IMPROVING DISEASE SURVEILLANCE PROGRAMS IN LIBERIA

by
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Abstract

Background: The 2014-2016 Ebola Virus Disease outbreak in West Africa highlighted the danger of emerging infectious diseases in areas with weak health systems. In Liberia, the outbreak resulted in over ten thousand cases and five thousand deaths. Existing evidence on the spread of Ebola is based on smaller scale outbreaks, and there is a knowledge gap in understanding the drivers of the epidemic in this new setting. This work investigates the epidemiological parameters of the EVD outbreak in Liberia, characterizes the role of community event-based surveillance in outbreak control, and investigates the determinants of performance of community health workers in those programs.

Methods: Paper 1 uses surveillance data generated during the EVD epidemic in 2014 and 2015 to link data generated by case investigations, treatment units, and epidemic control measures. We report changes over time in reproduction numbers, coverage of control measures, case fatality ratios, and the odds ratios of selected demographic, risks, and exposures. Paper 2 uses data from a community surveillance pilot project and the disease reports in 2016 to examine the design and implementation of a Community Event-Based Surveillance (CEBS) program, its sensitivity and positive predictive value, and evaluate domains of sustainability. Paper 3 evaluates the performance of community health workers in CEBS, examined through estimating odds rations for indicators of reporting, trigger recall, information sources, and process knowledge.

Results: We identified 10,280 cases (Attack Rate: 5.3 per 1,000) and 5,049 Ebola-related deaths (Case Fatality Ratio: 48.4%). The estimated basic reproduction number (R0=1.72) was one of the lowest estimates for EVD outbreaks. We show that the coverage of

contact tracing was low, covering a maximum of 21% of cases, and Ebola Treatment Unit (ETU) usage rose through the epidemic. There was a large increase in coverage of interventions following a reorganization of outbreak coordination in August, coinciding with a shift towards inclusive community outbreak control strategies. In Paper 2, we report that the CEBS pilot project in Liberia captured an average of 157 alerts and 37 suspect cases per week of the 12 reportable epidemic-prone conditions. The majority (95%) of alerts met the case definition. CHWs were most able to recall endemic conditions. We also identify and summarize four major designs of CEBS programs and suggest the Liberia CEBS structure as an active response program was unsustainable due to challenges in political support, organizational capacity, and financial sustainability. In Paper 3, we show that reporting at least one trigger was negatively related to the walking time of more than one hour from the health facility (OR=0.30, 95%CI 0.17-0.52). CHWs who were satisfied with their incentive were more likely to recall triggers (OR= 2.05, 95%CI 1.39-3.04), recall program protocol (OR=1.65, 95%CI 1.645-2.40) and have more information sources (OR=1.7, 95%CI 1.16-2.50).

Conclusion: There was substantial subnational variation in Ebola transmission and epidemiological parameters over space and time. Community engagement improves coverage of control activities during outbreaks, reduces risks and exposures to limit transmission. Community surveillance programs have the potential to improve timeliness of outbreak detection if countries with limited resources carefully define program goals and structure, proactively solve transportation and reporting barriers, and monitor CHW performance in relation to supervision and incentives.

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List of Terms and Abbreviations

ACCEL	Academic Consortium Combating Ebola in Liberia
ACF	Action Contre la Faime / Action Against Hunger
AFP	Acute Flaccid Paralysis
AFRO	Regional Office for Africa WHO
APL	JHU Applied Physics Laboratory
BCG	Border Coordination Group
CBIS	Community Based Information System
CDC	US Centers for Disease Control
CEBS	Community Event Based Surveillance
CHA	Community Health Assistant
CHAI	Clinton Health Access Initiative
CHD	Community Health Department
CHSD	County Health Services Division
CHT	County Health Team
CHW	Community Health Worker
CSH	Collaborative Support for Health Project
CSO	County Surveillance Officer
DHIS	District Health Information System
DPC	Disease Prevention and Control
DQA	Data Quality Audit
DSIS	Disease Surveillance Information System
DSO	District Surveillance Officer
eDEWS	Electronic Disease Early Warning System
EOC	Emergency Operations Center
EPI	Expanded Programme on Immunizations
EPR	Epidemic Preparedness and Response
EVD	Ebola Virus Disease
EWARN	Electronic/Early Warning and Alert Response Networks
FETP	Field Epidemiology Training Program
HF	Health Facility
HIS	Health Information System
HIV	Human Immunodeficiency Virus
HMER	HMIS, M&E, Research
HMIS	Health Management Information System
HMN	Health Metrics Network
ICT	Information Communication Technology
IDSR	Integrated Disease Surveillance and Response
IHR	International Health Regulations
IMS	Incident Management System
IOM	International Organization for Migration
IPC	Infection Prevention and Control
IRC	International Rescue Committee
JEE	Joint External Evaluation
JHU	Johns Hopkins University
JICA	Japan International Cooperation Agency
LIS	Laboratory Information System
LISGIS	Liberia Institute of Statistics and Geo-Information Services
LMDC	Liberia Medical and Dental Council
LMH	Last Mile Health
LMIS	Logistics Management Information System
M&E	Monitoring and Evaluation
MFL	Master Facility List
MNDSR	Maternal and Neonatal Death Surveillance and Response
MOH	Ministry of Health
NDSTWG	National Disease Surveillance Technical Working Group

NND	Neonatal Death
NNT	Neonatal Tetanus
NPHIL	National Public Institute of Liberia
NSTCC	National Surveillance Technical Coordination Committee / Core
ODK	OpenDataKit
PIH	Partners in Health
POE	Points of Entry
REDISSE	West Africa Regional Disease Surveillance and Response
RFA	Request for Application
SARA	Service Availability and Readiness Assessment
SIA	Strategic Information and Analysis
SME	Subject Matter Expert
SOP	Standard Operating Procedures
SPSS	SPSS Statistics Package
STATA	STATA Statistics Package
SWOT	Strengths Weakness Opportunity Threat Analysis
TB	Tuberculosis
TOR	Terms of Reference
TWG	Technical Working Group
UNFPA	United National Population Fund
UNICEF	United Nations International Children's Fund
USAID	United States Agency for International Development
USGOV	United States Government
VASA	Verbal and Social Autopsy
VHF	Viral Hemorrhagic Fever
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization

1 Introduction

Emerging infectious diseases (EIDs) pose a significant threat to international health and economy.[1,2] Overall, infectious diseases account for 15% of deaths globally. The most affected are marginalized and disadvantaged populations. Infectious disease in low-income countries accounts for one-third of the disability-adjusted life years (DALYs) burden.[3] EIDs are emerging or resurging diseases which "have newly appeared in a population or have existed but are rapidly increasing in incidence or geographic range."[1] They are among the most pernicious public health threats, known colloquially as pestilence or plague, and can present acute threats such as SARS, or entrenched outbreaks which develop into an endemic burden, such as AIDS. The incessant rise of EIDs is ascribed to changes in socioeconomic and ecological factors, including climate change and infrastructure development.[2,4–6] Jones et al. (2008) use population density and growth as proxies for the anthropogenic factors, and predict that the highest risk geographies for new EIDs are concentrated in lower-latitude low-income countries.[2]

Health systems in these regions are ill-equipped to respond to large scale outbreaks.[2,7] The 2014-2016 West African Ebola virus disease (EVD) outbreak demonstrates the danger EIDs pose to unprepared health systems. EVD outbreaks have historically been contained to smaller outbreaks in Central Africa.[8] The West African outbreak resulted in a reported 11,308 deaths and 28,610 cases in seven countries.[9] The health systems in the three most heavily affected countries, Liberia, Sierra Leone, and Guinea, were quickly overcome by the number of cases, and outbreak control measures were limited by insufficient numbers of trained staff, unprepared leadership in the early

days, community stigma, inadequate communication infrastructure.[10] The outbreak cost the three affected countries an estimated $53.2 billion in lost GDP (2014 USD), with $18.8 billion of these losses related to economic and social burden of non-Ebola deaths resulting from lack of basic health services and vaccination campaigns during the epidemic.[11] The extent of the outbreak and the overwhelming response needed to stop transmission was a call to action: disease surveillance in fragile countries must be modernized and become more responsive to changing health threats.

1.1 Study Context

Liberia, the setting for this dissertation, was especially vulnerable to health shocks. In 2003, the country emerged after two decades from one of the bloodiest contemporary conflicts in the continent. The extended unrest resulted in a large Liberian diaspora and refugee population. An estimated 86% of the population are displaced.[12] Post-conflict efforts prioritized the provision of basic health service packages for the population.[13,14] These rebuilding efforts have flooded the health sector with financing; external donors in 2012 accounted for nearly 47% of the total health expenditure, with 35% coming from out-of-pocket spending.[12,15]

Contemporary Liberia remains among the poorest countries in the world, ranking 162 of 169 by GDP per capita, with a total GDP of 1.95 billion dollars in 2013.[16] Sustenance farming accounts for the majority of the labor force. The economy is largely agricultural, relying on exports of natural resources including rubber, diamonds, and palm oil. Liberia ranks 6th of 53 on the Ibrahim Governance Index for African Countries,

90th of 183 on the Corruptions Perceptions Index in 2011, and is classified by UNDP as a "Least Developed Country" with low human development, the lowest of 4 categories.[17]

The disease surveillance system in Liberia was unequipped to deal with a national emergency. No leadership structures existed to quickly respond to the rising crisis. The ability to create actionable information was limited; the surveillance system relied on passive, health facility-based reporting, and the country lacked trained field epidemiologists. Relationships with health providers and the community were already strained. The government often delayed payroll, and during the epidemic was unable to sustain hazard pay for health workers and contact tracers. Much of the public initially believed the outbreak was a manufactured crisis to silence the government's criticism. The relationship with the community was further threatened by controversial mandatory cremation and quarantine policies. The EVD epidemic further weakened the health system through nosocomial infections which resulted in the deaths of over 300 health workers.[18]

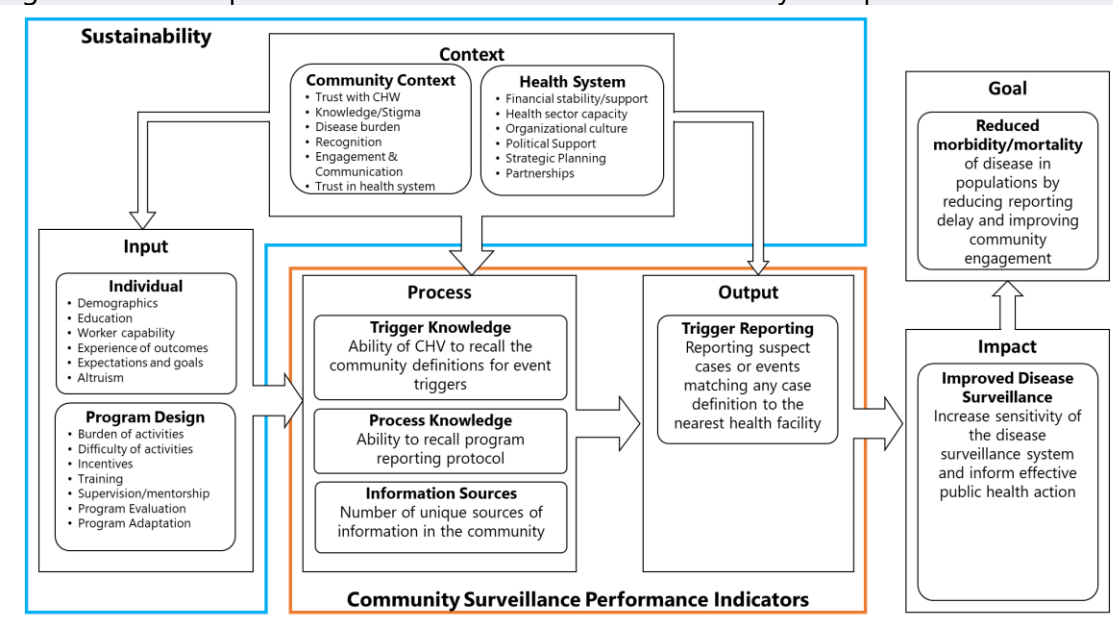
As the nature of the crisis became clear, a dedicated technical body was created to handle the crisis and further mobilize and coordinate international aid. Capacity was rapidly developed in all aspects of the disease surveillance and response structure, including a shift towards more context appropriate control meaures. As the epidemic waned, the focus of the incident coordination body shifted towards creating a responsive disease surveillance system, able to quickly identify and respond to potential health threats. This dissertation work was embedded in a larger project, *From Ebola Response To Sustainable Public Health Systems In Liberia* which supported that process. Led by Dr.

David Peters, the purpose of the project was to support Liberia's Ministry of Health and National Public Health Institute to develop and implement its vision for health information systems, with a focus on disease surveillance. This task was accomplished by tackling four pillars; strengthen coordination, build capacity, develop infrastructure for actionable information, and promote systematic evaluation. My role in the project was as the primary onsite technical assistance and *de facto* country director, providing support to the health information units in the Ministry of Health and the infectious disease units in the National Public Health Institute of Liberia.

1.2 SCOPE

During the EVD outbreak, community health workers played several important roles including contact tracing, health promotion and door to door case finding.[19] In this dissertation, we investigate the performance of disease surveillance during the EVD outbreak in Liberia, and how performance in the future can be improved by implementation of a community surveillance program. To frame our discussion of disease surveillance performance in context of community surveillance, we adapt the community health worker frameworks proposed by Gopalan et al. (2012) and Franco et al. (2002), and a health program sustainability framework proposed by Schell et al. (2013) in Figure 1-1.[20–22] In this framework, the nine domains of sustainability proposed by Schell et al. (2013) are categorized into contextual and input factors which encompass additional elements unique to community surveillance programs. Factors of the sustainability framework are further described in paper 2, and performance indicators are discussed further in Paper 3.

Figure 1-1. Conceptual Framework for Disease Surveillance system performance



In paper 1, we examine strength of the disease surveillance and effectiveness of control measures to halt transmission and reduce mortality during the outbreak (Impact and Goal boxes of Figure 1-1) by presenting a detailed overview of the epidemiological phenomena, risk factors, case fatality, and control measures. We created a comprehensive database by linking records from eleven databases, including surveillance data, laboratory data, treatment records, and control measures. The data were geolocated and deduplicated, allowing for a more accurate investigation of the coverage of outbreak control measures, and analysis in changes in transmission and case fatality over time than previously possible. The results of this paper aim to inform the characteristics of the outbreak in Liberia and identify the control measures and interventions which may prevent similar health threats the future.

Papers 2 and 3 of this dissertation stem from my involvement and subsequent leadership in the Technical Workgroup (TWG) for Community Event-Based Surveillance (CEBS), under the auspices of the National Disease Surveillance Strategy. CEBS is a program which enlists the community in disease surveillance by training community health workers to identify potential disease, and report/refer community members to the health facility. CEBS programs in Liberia were put in place during the tail-end outbreak to improve community engagement and maximize the sensitivity of the surveillance system.[23,24] The most extensive program was implemented by the International Organization for Migration in the eight counties with international borders, responding to concerns of re-infection from Sierra Leone and Guinea from the "high mobility of populations and cross-border movement of infected travelers."[25–29] With the epidemic waning in 2015, the IOM CEBS project shifted towards an integrated approach, adopting the disease triggers proposed by the TWG for surveillance of IDSR conditions. This program served as a pilot for the national CEBS program. Paper 2 compares the results of the CEBS program against the disease reports in the national surveillance database to examine the performance of the pilot in sensitivity and specificity of the disease triggers (Sustainability and impact box of Figure 1-1). We also conducted a desk review of documents and in-depth interviews to ascertain whether such a program would be sustainable in Liberia.

The relationship between input and contextual factors on CSW performance is the topic of Paper 3 (CSW performance and input factor boxes of Figure 1-1). We investigate the determinants of performance of community health workers to report

cases, recall triggers, gather information sources and recall the reporting process. The Liberia CEBS pilot was ambitious in design. The program targets epidemic-prone diseases, which require reporting within a 24-48-hour period. The real-time nature of the CEBS program is unique and presents challenges in an environment with little in the way of transport infrastructure. The paper identifies approaches, designs, and reforms which may impact the performance of community health workers in a surveillance program.

This dissertation is intended to elucidate how the EVD outbreak in Liberia evolved and the describe the role of community interventions put in place to prevent the next outbreak. As other resource-limited countries consider institutionalizing community surveillance programs as part of routine disease surveillance, I hope they may learn from the work and progress Liberia has made towards creating a more resilient health sector.

2 2015-2016 Ebolavirus Epidemic in Liberia: An Epidemic Post-Mortem

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2.1 Abstract

Background: Reports of Ebola in West Africa surfaced in January 2014. The resulting epidemic was worse than anticipated in both the duration and extent by public health officials. We aimed to document and describe the key epidemiological features of the epidemic in Liberia, including the risk factors and the impact of interventions.

Methods: The Liberia Ministry of Health and partners collected information on EVD cases, and contact tracing, dead body management, and treatment control measures for reporting to the Incident Management System. A comprehensive database was constructed by matching records in each of the eleven compiled databases through a customized deterministic matching algorithm. We conducted descriptive analyses over time and location of the epidemiological characteristics (caseload, reproduction numbers, case fatality rate, and transmission delays), surveillance system performance (timeliness, cases reported after death, case definition diagnostics), and coverage of control measures (case participation in contact tracing, dead body management, and ETU usage). We also report the relative risk of becoming a case by exposure and background characteristics, including international travel, funeral attendance, health care workers, age, and sex.

Results: Symptom onset for the first known confirmed case of EVD in Liberia was on March 13th, 2014. Between March 1st, 2014 and December 31st, 2015, a total of 10,222 cases (Attack Rate (AR): 2 per 1,000) were identified in the linked database, with 5,049 subsequently confirmed by laboratory testing and 5,121 Ebola-related deaths (CFR = 48.4%). We find substantial variation in both metrics over time and location. AR was 5.3 in communities which reported at least one case. CFR varied from 7% and 74% between ETUs, with clear trends by age and phases of the epidemic. 51,791 individuals were tracked in Liberia for possible exposure to Ebola, including 20,522 contacts. We estimate the basic reproduction number to be 1.78. This is among the lowest estimates for an EVD outbreak, compared past outbreaks which have reported reproduction numbers between 1.4 and 4.7 in past outbreaks. The instantaneous reproduction number varied over time dependent on control measures and penetration into urban areas. The initial sustained drop in reproduction number coincided with the creation of the Incident Management System and revised community engagement strategy. Funeral exposure ((RR: 1.27 [95%CI: 1.21-1.34]), males (0.93 [0.90-0.96]), residence in rural areas (1.32 [1.28-1.35]), health worker status (1.09 [1.04-1.15]), and international travel (1.16 [1.09-1.22]) were identified as statistically significant risk factors. We show a large increase in timeliness in reporting after the initial crisis recognition phase, and an increase in coverage of contact tracing, ETU admissions, and safe and dignified burials among cases. Dead body tracing reported the highest coverage, covering 2 in 3 case fatalities, whereas contact tracing reached only 16% of reported cases.

Conclusions: We show the 2014-2016 West African EVD outbreak in Liberia was distinctive in context and extent of transmission, but not in the epidemiological parameters. We hypothesize the lower basic reproduction number was influenced by urban transmission, which lowered the reliance on superspreading events to sustain person-to-person spread. The spread to major urban centers, national capitals, and high mobility populations likely drove the high duration and case load. The previous largest outbreak occurred in a provincial city in DRC, where Ebola is endemic. There was substantial variation in epidemiological characteristics (such as CFR) over time, space, and by risk factors, and summary measures may not adequately describe epidemic dynamics. We find further evidence to support funeral exposures as a primary driver of transmission. The overall evidence is suggestive that improved coordination mechanisms and community engagement interventions were underlying mechanisms towards eventual elimination.

2.2 INTRODUCTION

In early 2014, Gueckèdou district in south-eastern Guinea confirmed active transmission of Zaire Ebola virus (EBOV/Ebola) and an outbreak of EBOV disease (EVD) cases. Over the next two years, the ensuing outbreak affected seven countries and infected over 30,000 people.[9] Public health officials did not anticipate the duration or extent of the outbreak and delayed mobilization of resources during the early response. Eventually acknowledging that the outbreak presented a major public health threat, the World

Health Organization (WHO) declared its third Public Health Event of International Concern (PHEIC) since the ratification of the International Health Regulations in 2005.

EVD is not entirely uncommon in the continent. Past outbreaks were concentrated in Central Africa in smaller, successfully controlled outbreaks which did not pose a serious regional threat. However, the extent of transmission in urban areas and resulting geographic spread in the 2014-2016 West African epidemic was unprecedented.[30]

The outbreak in Liberia constituted a complex humanitarian emergency; an acute public health threat layered over ongoing instability. The country was still recovering from two decades of civil war. The health system was fragile, and public trust in the quality of health service delivery and government at large was tenuous at best. At the time of the outbreak, the health system was focused on the delivery of basic health services. Public health structures to respond to national health threats were nonexistent, and donors supported much of the sector.[13,14] External funds account for nearly 47% of the total health expenditure in 2012.[12,15,31] Despite these challenges, country officials in partnership with aid organizations were able to eliminate EVD from Liberia and leverage the outbreak to create long-lasting capacity within the health system.

In this chapter, we present a post-mortem of epidemiological features of the completed outbreak in Liberia using the surveillance data collected between 2014 and 2015. These data were used for real time response during the outbreak, and in retrospect provide insight into EVD disease dynamics, the efficiency of control strategies, and recommendations for long term resilience.

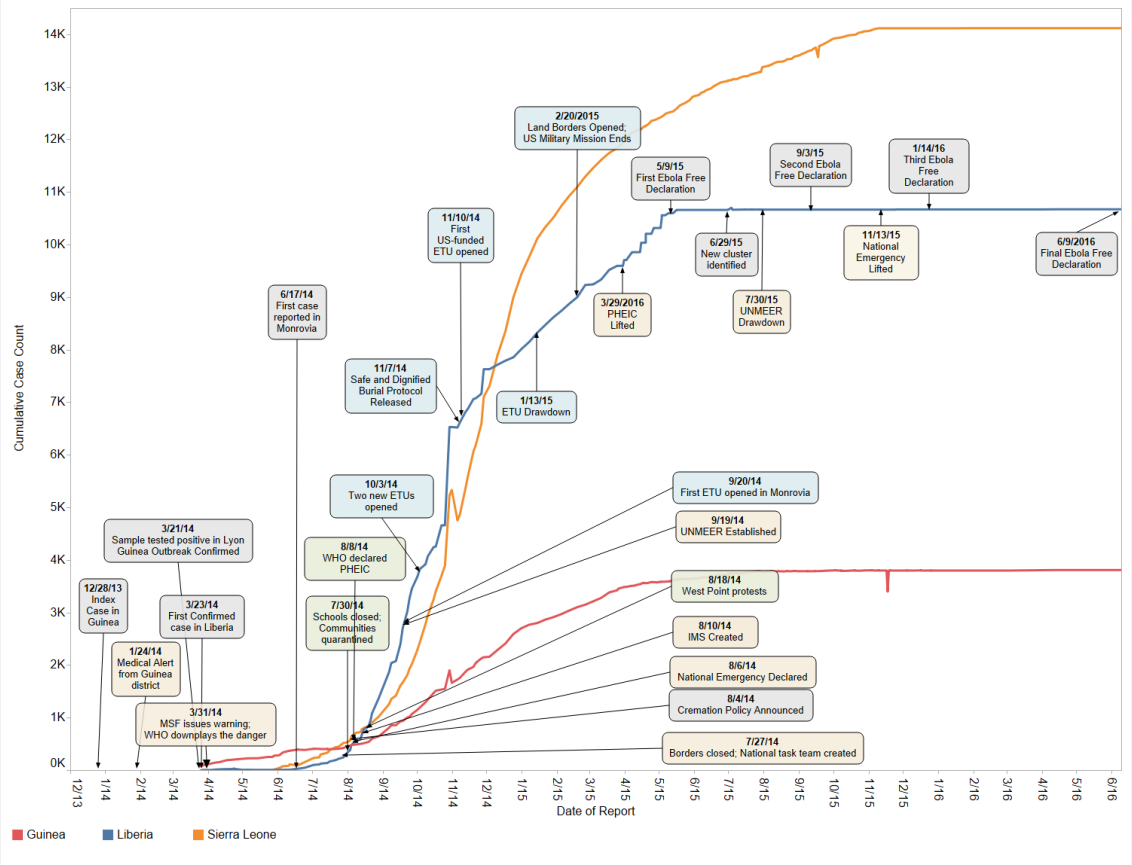
2.2.1 Timeline of Events

The putative index case, an 18-month old Guinean boy from the remote village of Meliandou, was presumed to be infected in December of 2013 from exposure to infected bats (Figure 2-1).[32] The Meliandou health post sent the first medical alert of a cluster of unknown disease to district health officials at the end of January 2014. The resulting investigation by national and international officials speculated cholera as the causative agent due to the clinical similarity. By February 1st the infection spread to the capital, Conakry, by an extended family member of the index case. No infection prevention precautions were taken against the yet unidentified disease at the hospital where the man died, resulting in exposure and infection of patients and health workers. Over the next months, the infection spread to neighboring prefectures and districts, traveling along trunk routes. On March 13th, Guinea alerted WHO to the unidentified disease, launching an investigation by national health officials which identified epidemiological links between seemingly disparate clusters. The Institut Pasteur confirmed the causative agent was a filovirus, and the next day narrowed to Zaire Ebolavirus, the deadliest of Ebola's common strains. By March 23rd, the Guinean government and WHO publicly announced an outbreak of EVD with 49 cases reported.

Liberia reported the first confirmed case at the end of March. This first reported case died, and the sister traveled while symptomatic to Margibi County with her two-year-old child to her home at the Firestone Rubber Plantation.[33] By March 30th, Liberia reported eight cases from Lofa, Margibi, and Nimba counties. Facing an increase in caseloads and cross-country transmission, Medicins Sans Frontiérs (MSF) warned the

outbreak was unprecedented in both location and magnitude. WHO dismissed the warning as alarmist and maintained the outbreak could be controlled with existing resources, with WHO playing its normative advisory role.

Figure 2-1. Timeline of the West African EVD outbreak in three most affected countries



Country case counts and events based on reporting by WHO Sitreps, archived by CDC[9]

Through April and May, caseloads in Liberia remained steady and relatively low. The infection reached the capital Monrovia on June 17th. The capital city was incapable of managing the deluge of infections. Within the next week, MSF urged the need for a massive international response, a warning again ignored by WHO until two months later.[34,35] In the meantime, management of control activities was left to the rather weak national disease surveillance system, WHO and CDC epidemiologists, and NGOs with a

pre-existing presence in the country. MSF set up EVD Treatment Units in Foya county to aid in rapid isolation and treatment of suspected cases while providing basic infection prevention and control measures to minimize nosocomial transmission to health workers. Samaritan's Purse also set up ETUs but withdrew after staff became infected. As the caseload rose, the danger of a propagated and uncontrolled outbreak in West Africa became clear. The United States Centers for Disease Control activated its Emergency Operations Center on July 9th to coordinate its field response. The Liberian government struggled to handle the rising emergency and created a national task team at the end of July, closed all borders and schools, and quarantined infected communities.[24] August saw an accelerating caseload. Liberia declared a national emergency on August 8th, followed two days later by the United Nation's PHEIC declaration. The World Bank pledged 200 million USD to support outbreak control, the US activated its Disaster Assistance Response Teams (DART), and a range of NGOs assisted the national government in dead body management, water and sanitation, infection prevention and control, case management, and disease surveillance.

The epidemic overwhelmed the health system, prompting the Ministry of Health to erect a parallel incident management system (IMS) to streamline decision-making.[36,37] While initially headed by the Chief Medical Officer, the organization of the IMS was shifted towards a self-contained and streamlined structure headed by an Incident Manager. Delegating epidemic coordination to the IMS also allowed the Ministry of Health to focus on the crumbling health sector.[38] The IMS focused on four pillars of

response; 1) early detection, isolation, and treatment; 2) safe transport of patients; 3) safe burial; and 4) infection prevention and control.[24]

Before the outbreak health workers had been protesting the government about lack of pay and missed payments. Rumors abounded that a desperate administration manufactured the current crisis. Trust was further strained when a cremation policy was announced in early August, a contentious proposition for Muslim and tribal communities. Families of EVD cases were also dismayed with the destruction of property following sanitization of infected household items and intermittent food supplies during the quarantine.[39] Tensions spilled over at Westpoint, a dense slum in downtown Monrovia, when protesters broke the IPC barrier of the local health facility, posing a considerable exposure risk. The military was brought in to enforce a quarantine, and during a protest, one person died in a standoff with authorities on August 18th.

Distrust of health officials and sustained depletion of already weak health systems through nosocomial transmission made it difficult for countries to extend disease surveillance and control measures into more remote regions.[40] With MSF leading the charge since early spring; a complex pluralism of bilateral, multilateral, NGOs and national organizations had flowed into Liberia attempting to stem the rising tide of EVD cases.[41–43] Under the guidance of IMS, disease control interventions supported by these organizations and public sector health workers were standardized under the umbrella of the national government. In response to the riot, the IMS pursued a central and culturally appropriate community engagement strategy. County health teams and NGOs had transitioned away from the cremation policy towards providing culturally competent

dead body management through the Safe and Dignified Burial program. Contact tracing was active in most areas of the country and were able to link to rapid response teams when cases were identified. Investments were made into hospitals and ETUs to bolster infection prevention and control standards. Capacity building within the county and national disease surveillance staff focused on developing analytical and epidemiological skillsets. Laboratory infrastructure and staff competency also surged, with regional laboratories being built around the country. Logistical clusters supported sample transport from health facilities to laboratories, health worker transport from communities to rural health centers, and ambulance transport for patients from communities and between referrals. The Ministry of Health developed guidelines for health promotion which outlined a culturally appropriate and consistent messaging strategy.

Incidence peaked in September, with more than 750 cases reported per week. Growing disease burden, episodes of international transmission, and rising pressure to address the epidemic galvanized further international support. On September 16th, the US committed a military presence to support building EVD treatment units in addition to growing the existing CDC and USAID assistance. In mid-September, the United Nations Mission for EVD Emergency Response (UNMEER) was established by the United Nations Secretariat.

By October, the situation began to stabilize with cases decreasing week by week; though prolonged high incidence in Sierra Leone and the possibility of hidden transmission chains were a constant threat. By November 10th, the first of the US-funded ETU's opened in Bomi County. As the epidemic wore on, a pattern of mini-epidemics

emerged, hampering regional isolation efforts. EVD cases flared up in a community, quickly spread, before dying out. Half of the new cases were localized in remote, rural areas.[24] To contain these rural and peri-urban epidemics, IMS put into place the RITE strategy, Rapid Isolation, and Treatment of Ebola. RITE empowered counties to form rapid response teams to respond quickly to hotspots.[24] In December, a new transmission chain was discovered in St Paul River Bridge, a peri-urban community on the outskirts of Monrovia. Overcoming stigmatization in the community, inadequate HCF triage, lack of recognition of cases, and incomplete identification and follow-up, public health officials were able to respond and eliminate the chain quickly.[44]

ETU usage at this time had fallen, and by mid-January plans for existing buildings were downsized. By the end of February, the US military withdrew after completing the new ETUs, and at the end of March 2015, the PHEIC was lifted. In May, Liberia announced that all known lines of transmission were extinguished and no case had been identified for the past 42 days. The declaration started 90 days of WHO protocol for heightened surveillance, including community-based surveillance and postmortem testing for all reported deaths.[45] Warning that flare-ups were likely as latent transmission chains came to light and persistent infection was still possible, WHO announced what would be the first of four Ebola-free declarations on May 9th, 2015.[46] Flare-ups occurred over the next year, from importation from an outbreak in N'zerèkorè district of Guinea[47], latent infections, and discovery of new transmission chains.[45] UNMEER began its drawdown on August 30th, and the national emergency was lifted on November 13th, 2015. The final EVD free declaration was made in June of 2016.

After the first outbreak free declaration, attention and investments shifted towards building a resilient health system.[48] Part of this strategy was reintroduction and implementation of an Integrated Disease Surveillance and Response (IDSR) program, a surveillance framework used in various countries in Africa devised by AFRO region office of WHO.[49,50]

2.2.2 Overview of Control Measures

With the lack of licensed pharmaceuticals or vaccines, outbreak control relied on nonpharmaceutical interventions.

Case Management and Treatment

Health facilities in Liberia lacked isolation capacity to treat EVD cases without risking exposure to health care workers and other patients. In addition to clinical care, ETUs were constructed to provide rapid isolation and treatment to EVD cases while minimizing nosocomial transmission. ETUs also acted as a logistics backbone for sample transport, dead body management through the morgues, disposal of biowaste, and training health workers in infection control. Each ETU generally included a "green zone" free of EVD contamination, and "red/hot zone" for EVD cases and health workers with full personal protective equipment (PPE). Cases were admitted from community walk-ins, referrals from case investigation and contact tracing teams, and triage at health facilities. Without any pharmaceutical cure, ETUs relied on basic supportive care. Patients were provided with oral and parenteral volume replacement, analgesics, electrolytes, and vitamin supplements. The treatment protocol was not standardized, and some NGOs did

not provide intravenous rehydration in mildly symptomatic cases to reduce the risk of exposure.[24]

Dead Body Management

Tribal traditions and religious rites surrounding funerals created a high risk of exposure during the burial of Ebola-infected individuals.[51] In some tribes, family members and caretakers sleep in the same room as the body until burial, and during the funeral give a final embrace. In Muslim tradition, dead bodies are washed and wrapped in white cloth before burial within 24 hours of death. Initially, Liberian authorities mandated cremation for dead bodies with suspected EVD infection to reduce transmission risk, with significant community resistance. Dead body management programs, termed "Safe and Dignified Burial" were started to address burial in a culturally sensitive manner. 54 dead body management teams were active in all fifteen counties by September 2014. The teams worked with communities to disinfect the body, and demonstrated the use of personal protective equipment to family members who wanted to be engaged in the burial. A large cemetery was created in the Disco Hill community in Margibi for Ebola-infected individuals.[24,52] All unexplained deaths, and later all deaths, were swabbed and positive rapid tests were followed by confirmatory testing.

Contact Tracing

Contact tracing aims to identify all possible individuals with exposures to a case, stratify exposure by transmission likelihood, and monitor for signs of disease onset to provide timely treatment and minimize further secondary cases. Contact tracing

activities were active across all counties as a fundamental part of case investigation. Six types of exposure were defined, (1) sleeping or eating in the same household; (2) direct physical contact with the body; (3) touching bodily fluids; (4) manipulating clothes or other objects; (5) breastfeeding; and (6) attending a funeral of a deceased case. Case investigation teams solicited a list of names which the case encountered during the transmissible period. Contact tracing teams visited each contact twice a day for 21 days and monitored for signs and symptoms of EVD infection. Each contact tracer was assigned up to 20 contacts.[39] During the follow-up period, contacts with a high-risk exposure (such as direct contact with bodily fluids) were requested to maintain a voluntary quarantine within their house.[53] Food and water were provided during this period, and psychosocial teams made periodic visits. Written documentation was provided to employers and schools to excuse the absence and again to provide confirmation of completion of the quarantine without signs or symptoms. To prevent stigmatization of contacts following quarantine a graduation ceremony was held to mark the occasion of discharge.[39]

Health Promotion, social mobilization, and psychosocial support

Communication and mobilization took a rare front seat; this was the first outbreak to have a dedicated health promotion logistical cluster. The health promotion cluster developed a core package of promotion materials, translated to local dialects. Health promotion during the early weeks of the outbreak targeted EVD denial and skepticism. As cases began to recover, messaging shifted towards underscoring the potential for survival with treatment, preventative measures, and the importance of Ebola elimination.

Messaging was disseminated through the newspaper, radio and TV addresses, community health talks, comedians and drama troupes. The most effective dissemination was door to door, due to the strong tradition of oral communication. The concerted push on social mobilization and health promotion included training local leaders and community health volunteers on behavior change strategies, radio campaigns, and reporting hotlines.

Community health workers, religious leaders, traditional healers, chieftains, school teachers, and other key stakeholders in the community were trained by NGOs as frontline mobilizers.[24] These mobilizers were also taught basic surveillance, and could report cases. In communities with recent infection, "ring interpersonal communication" activities focused psychosocial support and prevention awareness on helping interrupt transmission chains.[54] Direct support was also provided to families of EVD cases, survivors, and EVD negative contacts. Large scale meetings were held with community leaders to drive support for outbreak response.

Health system capacity, coordination, and leadership

Health system responses were aimed at improving the capacity of the health system to respond to the rising emergency. Chief among these was establishing the Incident Management System to coordinate surveillance and response between the Liberian Ministry of Health and partners, mobilize and direct resources, and communicate with the public with a singular voice. Responses included updated laboratory infrastructure, logistical support for referrals and sample transport, and developing an informatics backbone.[55]

In addition to structural changes, capacity building of staff was targeted. Epidemiologists working with international organizations were embedded in national, county, and district health teams, and worked with Liberian staff to increase the capacity of epidemiologists. Laboratory staff were trained in EVD assays and algorithms, and international data management teams supplemented Liberian resources. Teams worked together to devise systems and procedures for daily and weekly outbreak reporting.

2.3 METHODS

We performed a retrospective descriptive analysis of case records, ETU discharge papers, contact tracing, and dead body management databases provided by the Liberian Ministry of Health.

2.3.1 Disease Investigation

Case Investigation

Passive and active surveillance activities were conducted by the district, county, and national surveillance officers with support from aid organizations. Passive surveillance included reports from health facilities, treatment centers, funeral homes, and through community hotlines. Active surveillance was ongoing through contact tracing, case and key informant interviews, burial teams, and frontline workers.

For suspect cases, data on demographics, residence, symptoms, and exposures were collected from the case and key informant interviews on standardized investigation forms. Samples were taken from cases when possible and sent for diagnosis to the nearest laboratory equipped for EVD rapid and confirmatory testing. There were several regional labs in Liberia equipped for testing, with the reference laboratory, Liberia

Institute of Biomedical Research (LIBR). For negative samples, a repeat sample was taken after 48 hours.

Case information and laboratory results were used for epidemiological classification of cases. Epidemiological classification designates the likelihood an individual is infected with EVD based on laboratory results, signs and symptoms, and epidemiological history. Case classification was based on WHO guidance and assigned at the start of a case investigation as either suspect or probable and updated when the case is closed as confirmed or not a case. Classifications were updated periodically in large batches to account for laboratory results and epidemiological information available after case closure. During the height of the epidemic, the health system was stretched beyond capacity, and many cases were not classified to these final categories.

Table 2-1. Expanded case definition for EVD

Suspect case	Individuals with a sudden onset of high fever and reported contact with an EVD case or a sick or dead animal OR Individuals with a sudden onset of high fever and at least three Ebola-associated symptoms (nausea/vomiting, diarrhea, fatigue, loss of appetite, abdominal pain, headache, breathing difficulty, swallowing difficulty, hiccups) OR Individuals with unexplained bleeding OR Individuals with sudden and unexplained death.
Probable case	Suspect case diagnosed with EVD by a clinician OR A deceased suspect case epidemiologically linked to a confirmed case.
Confirmed case	A suspected or probable case with a positive laboratory result for EVD virus antigen by reverse transcriptase PCR (RT-PCR) detection of viral RNA OR

	A suspected or probable case with a positive laboratory result for EVD virus antigen by detection of anti-Ebola IgM antibodies.
Not a Case	Suspected or probable case with no specific antibodies, RNA, or detectable antigens on laboratory testing (RT-PCR or anti-IgM antibodies)

The outbreak data also include individuals with a identified exposure but without a case record. Classifications for these observations can be:

- *Contacts,* identified by soliciting names of all individuals who came in contact with a case. Contacts were subsequently followed by contact tracing teams. Contacts may have become symptomatic, but a case investigation or admission into treatment must have occurred to be considered a case.
- *Sources,* Ebola-infected individuals a case encountered and potentially were the transmission source. Sources establish an epidemiological link, but EVD infection cannot be confirmed in the source case unless a case investigation was completed.

Individuals without an epidemiological linkage or a case investigation are assigned an unknown classification. Many unknown classifications in the database are a result of the Safe and Dignified Burial program, indicating burials which took place before a sample could be tested. We report the sensitivity, specificity, positive predictive value, and negative predictive value diagnostics for the suspect case definition, signs, and symptoms.

2.3.2 Data Sources

The data collected during the epidemic are rich but inconsistent quality. Case investigations, laboratory results, treatment records, and outbreak control measures were collected in fragmented databases, and unique identifiers were not universally implemented. Limited IT infrastructure led to the bulk of data to be collected initially on standardized paper forms and entered into electronic databases. The bulk of cases were entered into the Viral Hemorrhagic Fever module of EpiInfo, an epidemiological surveillance tool maintained by the US Centers for Disease Control and Prevention. The module had been designed for the smaller outbreaks seen in Central Africa, and the detailed level of information and lack of in-country experience with the platform resulted in data managers and analysts working overtime to produce the daily analyses required to respond to the outbreak.[24] In mid-December 2014, the case investigation data was migrated to the DHIS2 platform's line list module. While not intended to serve real-time data transactions, there was an extensive local capacity to operate the platform, and the caseload had decreased to a manageable trickle. The DHIS database served as a final record rather than a living dataset, with most of the analysis in the last leg of the epidemic done using Microsoft Excel.

In 2015, a task team of health information specialists attempted to digitize all outbreak data, including ETU records and laboratory results, for final storage in the master DHIS2 dataset. The team conducted chart abstractions at each EVD Treatment Unit to identify cases with a treatment record but without a corresponding case investigation. Data from laboratories were added to cases and used in reclassifying the final epidemiological status of the individual. Record keeping at the laboratory was

especially problematic, with numerous occurrences of orphaned lab samples which arrived without proper identification, and could not be connected to any case. Laboratory data were collected in Excel sheets, with minimal standardization between laboratories.

Data generated by outbreak control interventions were managed by county health officials, transmitted to the national level in aggregate.[24] We collected contact tracing paper forms into a Microsoft Access Database. The Environmental Health unit administered dead body management databases within the Ministry of Health in separate Excel sheets.

Key variables from all datasets were extracted and collated to form the comprehensive outbreak record reported in this paper. We expect the final dataset to contain gaps due to underreporting and record loss. The data from cases and interventions in Montserrado County are the most complete as NGOs supported the Montserrado county team, and gathering the hard copies of forms was logistically easier. Records with either an unknown county of the report or without a patient name were dropped.

The dataset reported in this paper excludes cases reported in 2016, specifically the confirmed cases generated by the last cluster. The index case for this cluster is the wife of an case who died in Guinea. The woman traveled to Monrovia before dying herself. It is assumed that this cluster was not associated with the primary transmission chain which was eliminated in September of 2015. Data for this cluster was managed separately and not included with the data from the epidemic.

Identifying duplicate cases

In the merged database, duplicates were identified by a deterministic matching process which evaluated potential case pairs against a series of keys. Each key was manually constructed, containing a combination of onset time, gender, patient name, the address of onset, date of death, patient age, and unique IDs. Keys were also created which took into consideration name rarity, date transpositions, and reversed first/last names. The set of variables included in each key were determined iteratively - results of each key match were reviewed and keys which created false matches were removed or reformulated. The list of keys is given in Annex See Annex Table 7-1. Any pair of records which matched exactly on all the data elements within at least one key were considered a match. The results of the deduplication between databases as shown in Table 2-2. By including contacts and sources as separate observations in the deduplication process, we were able to partially recreate segments of the transmission tree (examples given in Appendix).

Table 2-2. Record matches between EVD case, treatment, and intervention datasets

Percent of cases shared with comparison database	Databases									
	Case Linelist (DHIS)	Safe and Dignified Burials	Contact tracing source cases	Case Linelist (EPI Info)	Laboratory	Contacts (Source Cases)	Contacts	Health Care Workers	ETU Admissions	ETU Admissions (Survivors)
Case Linelist (DHIS)		6.7%	5.6%	1.4%	6.4%	2.4%	1.7%	22.9%	6.8%	8.1%
Safe and Dignified Burials	6.2%		11.0%	2.0%	11.2%	1.9%	10.4%	41.4%	34.6%	3.1%
Contact tracing source cases	6.0%	12.9%		3.6%	6.1%	4.4%	11.7%	24.3%	10.8%	10.7%
Case Linelist (EPI Info)	4.8%	7.3%	11.5%		10.4%	1.8%	5.4%	7.1%	10.2%	9.6%
Laboratory	20.5%	39.6%	18.2%	9.9%		3.6%	15.9%	44.3%	50.6%	58.6%
Contacts (Source Cases)	2.2%	1.9%	3.7%	0.5%	1.0%		4.0%	4.3%	1.8%	1.3%
Contacts	0.7%	4.9%	4.7%	0.7%	2.1%	1.9%		2.9%	4.1%	3.4%
Health Care Workers	1.0%	2.0%	1.0%	0.1%	0.6%	0.2%	0.3%		1.5%	0.1%
ETU Admissions	11.1%	62.0%	16.4%	4.9%	25.8%	3.2%	15.6%	58.6%		83.1%
ETU Admissions (Survivors)	5.7%	2.4%	7.0%	2.0%	12.8%	1.0%	5.5%	1.4%	35.8%	
Cases in Database										
Unique	1,121	408	1,067	4,575	3,041	764	490	8	412	83
Total	1,621	1,483	1,739	5,519	5,220	1,479	703	70	2,659	1,144
Records in Database										
Unique	4,377	2,211	1,102	5,025	6,660	765	19,693	8	1,006	83
Total	8,109	6,599	2,375	5,593	13,485	1,596	20,522	72	4,849	1,471

Total Cases in final database	10,280
Total records in final database	51,479

Cells show the percentage of records in the database which are also in the comparison database ([# cases which are both databases]/[total cases in column database]). Colors denote the percentage – green is a high match percentage and red is a low match percentage.

On occasion, datasets were forked from the central databases and maintained externally. For instance, the national survivor dataset was maintained from a snapshot of the ETU dataset, and cases were added when survivors came forward to claim benefits. Another example is the dataset of health workers who died from EVD, maintained based on a snapshot of the DHIS2 dataset. These forked databases resulted a high match percentage between the Survivor and EPI Info databases, and the ETU survivors and ETU admissions.

Data Cleaning and Reclassification

Data were reviewed for common errors and completeness. The location for each case is summarized by the county, district, and village of residence. We used the Liberia Institute of Statistics and Geo-Information Services (LISGIS) 2008 Place Code Database to

clean location to the village level. The 2008 populations were updated to reflect population growth up to 2016, using IMF, World Bank, and LISGIS country-wide growth estimates. Village names are often repeated or phonetically similar; all matches were manually reviewed, but misclassification is possible. Records which could not be matched to a village were assigned to the closest village to their latitude/longitude coordinates, when available. Municipalities were defined as any village within 20 miles from city center, and urban areas were defined as communities with a population larger than 3000 persons, consistent with the definition in the 2018 census.

The date of symptom onset is used for calculations of incidence rates and reproduction numbers. Dates of onset before 2014 and after 2016 were set to missing, as none of the datasets used in this analysis could plausibly contain dates in that range. In situations where the date of symptom onset is unknown, such as when the case is identified after death, the date of onset is estimated using the date of report minus the average report delay, date of contact minus the estimated serial interval, or the date of death minus the average time from onset to death.

Patient names and locations were cleaned using strict Levenshtein distance criteria, which standardizes strings which differed by less than 10% based on character deletions, substitutions, and insertions.[56] Patient gender, essential for identifying duplicates, was not included in some datasets. Missing gender was automatically assigned based on the first name if at least 80% or more of individuals with that first name in the dataset were of male or female gender. The time course of the epidemic was divided along epidemic weeks into four phases based on the observed epidemic trends of cases within Liberia.

We describe data across epidemic phases as defined by Nyenswah, Engineer, and Peters (2018).[57]

- Phase 1; crisis recognition; refers to the early organization of response, capturing the initial spread of EVD from the start of 2014 to May 21st, based on a post-hoc assessment which covers the ramp up in cases and terminates before the start of the largest transmission peak. Though the crisis recognition phase can justifiably be extended to early August when the national emergency and PHEIC declarations were issued, our more conservative definition focuses on the initial organization of emergency response partners, the ramp up in case identification activities, and early coordination structures.
- Phase 2 is the emergency phase; which covers the acceleration in incidence and the peak of the outbreak, from mid-August to mid-November 2014 (epidemiological weeks 34-46) and terminates in early September on the estimated date the instantaneous reproduction number fell below 1.
- Phase 3; is the declining epidemic and stretches from early September to the end of 2014. At this point, disease control strategies were standardized.
- Phase 4 is the long tail; covers the sporadic clusters throughout 2015.

2.3.3 Data Analysis

The serial interval is defined as the time between the date of onset of the primary case and date of onset of a secondary case. We calculated the serial interval from contact tracing data between confirmed cases and their confirmed contacts. Case pairs were excluded if the date of onset was estimated. The incubation period was measured

among contacts, as the time between reported exposure and the onset of symptoms. Duration until community death was measured among all cases as the time between the date of symptom onset to the date of death for cases without a record of admission to an ETU or health facility. The admission delay is defined as the time between symptom onset and admission into an ETU among cases with an ETU admission. The convalescence time is measured as the time from admission to discharge, and time to death measured as the length of time from admission to death in an ETU. All timescales are summarized by mean, standard deviation, median, IQR, and range, and compared to estimates from previous outbreaks when available.

The changes in transmission during an epidemic can be caused by contact patterns, control measures, change in infectiousness of a causative agent, or a decline in susceptible populations. Infectiousness of disease is commonly summarized by the basic reproduction number (R_0), which denotes the average number of secondary cases in a completely susceptible population. We calculate R_0 between April 1st and July 30th, before the reorganization of control measures by IMS and border closings and community quarantines, using the exponential growth model provided by the *R0* R package.[58] We also calculate the instantaneous reproduction number (R_t), which estimates the average number of secondary cases at a given point during the epidemic. When R_t falls below 1, the epidemic is unsustainable and will eventually extinguish. We estimated R_t using the methods proposed by Cori et al. (2013), using the *EpiEstim* R package.[59] The method relies on the calculation of the serial interval, discussed above. We mapped R_t over one year, from the beginning of April 2014 to the end of April 2015.

The delay in the start window allows for a more precise estimate, and the ending window was chosen as the last transmission chain connected to the broader outbreak (first detected on March 28th, 2015). The transmission for the flare-ups due to importation or unknown transmission are not indicative of a change in transmissibility. This analysis assumes the serial interval and reporting rates did not change significantly during the outbreak. The latter assumption is tested by correcting for underreporting rates. Instantaneous reproduction numbers for selected counties, district, and village are reported in the Appendix.

Case Fatality

Approximately 17% of cases had a missing vital status after matching to survivor and dead body databases. Over 80% of these cases with missing vital status were generated early in the epidemic or during the peak of the infection, where case investigation mechanisms were either not entirely in place or strained. In many cases, fatality was recorded at time of report, and there was no follow-up information available on the outcome. A common practice when using case line lists is to exclude both these records and cases found after the time of death to avoid biasing case fatality estimates. We believe any bias will be minimal in the comprehensive dataset as we can match to both dead body management and survivor records. Deaths are more likely to be captured by the surveillance system. We report case fatality using this standard method and recoding the cases with missing outcome information as alive. Case fatality was calculated over a 2-month window, with confidence intervals estimated by a normal Poisson distribution.

Control Measures

We define coverage as the proportion of cases (or case fatalities) which received the control measure. Coverage of contact tracing and ETUs was calculated among all cases, and coverage of Safe and Dignified Burial was measured for case fatalities. Participation in contact tracing was defined as being either a case or prior contact. Participation in dead body management was defined as appearing in the dead body management database, having a record for admission into an ETU, or an indication that an NGO or county burial team conducted the burial. ETU coverage was based on admission into a named ETU; hospitals, health facilities, and community care centers are not included in this measure. The percentage of cases which indicated participation was calculated in a 60-day window, with confidence intervals estimated by a logit transformed normal assuming a t-distribution.

Data for planned beds were taken from news articles, situation reports, IMS notes, and announcements by the government of Liberia, NGOs, and UN agencies. Actual and stretch capacity was based on regular updates made at meetings IMS and summaries reported by the US military, literature, and UNDP. Actual and case usage was determined based on admission and discharge dates in our database. For records with ETU admission dates but without death or discharge dates, we randomly assign a duration value from a Poisson distribution constructed from the mean convalescence time. The duration of ETU stay was imputed for 51.7% of records in this manner. Theoretical usage was calculated with the assumption that all cases used an ETU, and the dates of usage imputed from a Poisson distribution based on the date of onset, average

admission delay, and average duration in an ETU among cases which had an ETU admission. All estimates are calculated across a moving average of one-week window.

Exposures

We assessed the relative risk of infection (becoming a suspect, probable, or confirmed case) among four exposures reliably recorded in surveillance data; (1) health workers, (2) visits to sick persons in the hospital, (3) international travel, and (4) funeral attendance. Risks were measured among individuals with a known exposure status. Exposure to animals and breast feeding was not available for most cases. Unadjusted relative risk of background characteristics and exposures were estimated by logistic regression.

Observations during Phase 4 were removed from this analysis. Contact tracing was highly sensitive during this phase; contacts with even a slight risk of indirect exposure were solicited, and tracing was more likely to be initiated for suspect cases which were later classified as not a case. Surveillance data did not contain information on vaccination, and we were not able to remove vaccinated persons from the exposed population. Most vaccinations would have occurred in Phase 4 in the PREVAIL trail which started in February of 2015.[60] We assume the effect of vaccinations in Phases 1, 2, and 3 is extremely limited.

2.4 RESULTS

Symptom onset for the first confirmed case of EVD in Liberia was on March 13th, 2014. Between March 1st, 2014 and December 31st, 2015, a total of 10,280 cases were identified, with 5,049 subsequently confirmed by laboratory testing and 5,121 Ebola-

related deaths (Table 2-3). 51,791 individuals were tracked in Liberia for possible exposure to Ebola, including 20,522 contacts. Official estimates from CDC and WHO situational reports estimate 10,678 cases, with 3,163 confirmed and 4,810 deaths.

Table 2-3. Case Classification by Background Characteristics and Exposure Risks

Background Characteristic	Classification					
	Confirmed	Probable	Suspect	Not a Case	Case	All Records
Age in years						
0-9	532	294	204	2,942	1,030	3,972
10-19	698	379	244	2,202	1,321	3,523
20-29	1,112	516	402	3,530	2,030	5,560
30-39	1,116	518	469	3,464	2,103	5,567
40-49	801	418	417	2,664	1,636	4,300
50-59	397	220	196	1,842	813	2,655
60+	267	195	249	2,803	711	3,514
Gender					-	-
Female	2,428	1,310	1,008	16,520	4,746	21,266
Male	2,682	1,375	1,459	22,866	5,516	28,382
County					-	-
Bomi	119	70	92	707	281	988
Bong	181	72	153	997	406	1,403
Gbarpolu	21	8	10	449	39	488
Grand Bassa	75	98	61	1,126	234	1,360
Grand Cape Mount	107	81	100	554	288	842
Grand Gedeh	7	2	8	353	17	370
Grand Kru	25	18	16	387	59	446
Lofa	426	318	145	1,639	889	2,528
Margibi	420	508	411	3,067	1,339	4,406
Maryland	3	-	11	279	14	293
Montserrado	3,570	1,360	1,400	30,523	6,330	36,853
Nimba	112	134	57	411	303	714
River Cess	8	5	5	82	18	100
River Gee	9	7	5	346	21	367
Sinoe	27	4	11	246	42	288
Urban/Rural					-	-
Urban	3,889	1,645	1,571	30,576	7,105	37,681
Rural	1,210	1,029	914	10,552	3,153	13,705
Phase					-	-
Crisis Recognition	1,031	572	560	3,010	2,163	5,173
Emergency	3,684	2,009	1,653	17,548	7,346	24,894
Declining Epidemic	366	93	272	10,897	731	11,628
Long Tail	29	11	-	9,711	40	9,751
Health Care Worker					-	-
No	2,606	1,711	2,148	8,165	6,465	14,630
Yes	250	120	90	243	460	703
Travel History					-	-
No	1,038	950	1,273	7,049	3,261	10,310
Yes	156	125	134	242	415	657
Hospital Visit					-	-
No	1,002	965	1,212	5,756	3,179	8,935
Yes	131	49	128	1,517	308	1,825
Funeral Attendance					-	-
No	1,187	990	1,483	27,181	3,660	30,841
Yes	242	226	81	504	549	1,053
ETU Admission					-	-
No	1,852	1,673	2,182	35,424	5,707	41,131
Yes	3,215	1,002	260	5,124	4,477	9,601
Grand Total	5,110	2,685	2,485	41,166	10,280	51,446

CI = 95% Confidence Interval

Suspect cases reported in Phase 4 are excluded from the analysis. Results from the formal reclassification exercise were not available for this dataset.

Table 2-4. Case Fatality Rate by Background Characteristics and Exposure Risks

Background Characteristic	CFR			
	n	%	95% CI	
Age in years				
0-9	968	45.5	42.5	48.6
10-19	1,248	36.4	33.8	39.0
20-29	1,934	45.6	43.4	47.7
30-39	1,992	49.7	47.6	51.8
40-49	1,549	53.5	51.1	55.9
50-59	766	56.9	53.5	60.4
60+	678	61.2	57.6	64.8
Gender				
Female	4,412	47.1	45.7	48.5
Male	5,169	49.7	48.4	51.0
County				
Bomi	281	47.7	41.8	53.5
Bong	393	36.5	31.8	41.1
Gbarpolu	37	43.6	27.8	59.4
Grand Bassa	210	37.6	31.4	43.8
Grand Cape Mount	289	44.1	38.4	49.8
Grand Gedeh	17	29.4	7.1	51.7
Grand Kru	62	66.1	53.9	78.3
Lofa	872	57.1	53.9	60.4
Margibi	1,316	47.1	44.4	49.8
Maryland	14	64.3	38.2	90.3
Montserrado	5,698	49.6	48.3	50.8
Nimba	303	25.4	20.5	30.3
River Cess	27	77.8	58.0	97.5
River Gee	20	66.7	46.0	87.3
Sinoe	42	66.7	52.2	81.1
Urban/Rural				
Urban	5,893	49.2	48.0	50.3
Rural	3,664	46.5	44.8	48.3
Phase				
Crisis Recognition	2,041	65.3	63.3	67.3
Emergency	6,864	44.5	43.4	45.7
Declining Epidemic	675	37.8	34.2	41.3
Health Care Worker				
No	6,347	50.1	48.9	51.3
Yes	443	59.8	55.3	64.3
Travel History				
No	3,590	43.7	42.0	45.4
Yes	427	55.7	50.9	60.4
Unknown	5,564			
Hospital Visit				
No	3,624	44.3	42.5	46.0
Yes	308	46.1	40.5	51.7
Funeral Attendance				
No	3,624	43.1	41.5	44.7
Yes	308	58.3	54.2	62.4
ETU Admission				
No	5,422	0.50	0.49	0.51
Yes	4,159	0.47	0.45	0.48
Grand Total	10280	48.4	47.4	49.4

CI = 95% Confidence Interval

CFR = Case Fatality Rate; measured among only probable and confirmed cases (#deaths/#cases), assuming records with missing values are alive

Phase 4 was excluded from the analysis. Results from the formal reclassification exercise were not available for this dataset, and the case definition changed to include all deaths.

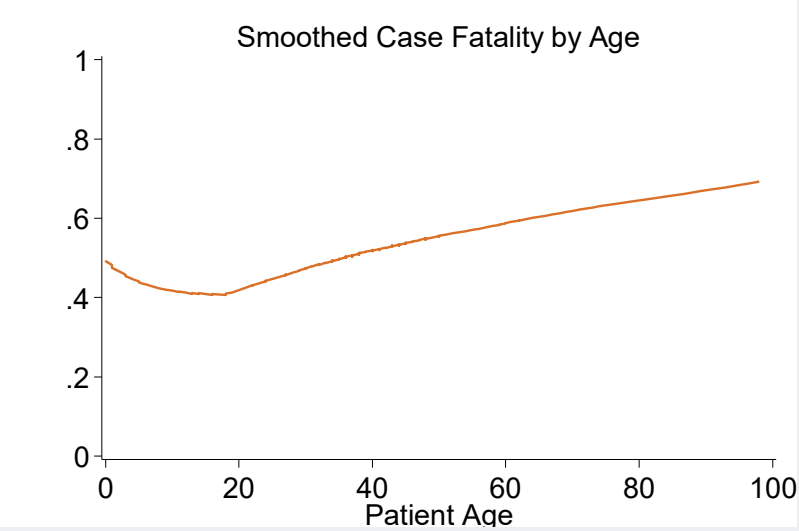
The demographic breakdown of case classification is presented in Figure 2-3. The overall attack rate for Liberia is estimated to be 2 cases per 1,000 persons when the entire population is considered susceptible. When considering only cases in the community (removing those who self-identified as a health worker) and the exposed populations in the villages and communities with at least one reported case, we estimate the attack rate to be 5.31 per 1,000. The overall case fatality rate is estimated to be 48.4%, with significant variation over time (Table 2-4). The estimate is among the lowest reported for an EVD epidemic (Table 2-7). One-fifth of cases took place during the crisis recognition phase. This phase during the early epidemic also reported the highest case fatality rate at 65.3%. The emergency response phase accounted for 70% of all cases, with 45% of cases occurring during the decline of the epidemic and less than 1% of cases occur during the phase of the long tail in 2015.

Table 2-5. Risk of Infection by Background Characteristics and Exposure Risks

Background Characteristic	Risk of Infection			
	n	RR	95% CI	p
Age in years				
0-9	2,032	0.91	(0.86 , 0.96)	<0.001
10-19	2,226	1.07	(1.02 , 1.12)	0.007
20-29	3,632	1.01	(0.97 , 1.06)	0.520
30-39	3,794	REF		
40-49	2,913	1.01	(0.97 , 1.06)	0.585
50-59	1,627	0.90	(0.84 , 0.95)	<0.001
60+	1,845	0.70	(0.65 , 0.75)	<0.001
Unknown	1,384	0.61	(0.57 , 0.67)	<0.001
Gender				
Female	8,574	REF		
Male	10,817	0.93	(0.90 , 0.96)	<0.001
County				
Bomi	546	1.06	(0.98 , 1.15)	0.168
Bong	851	0.95	(0.88 , 1.03)	0.194
Gbarpolu	77	0.99	(0.78 , 1.25)	0.934
Grand Bassa	491	0.88	(0.79 , 0.98)	0.017
Grand Cape Mount	638	0.93	(0.86 , 1.02)	0.122
Grand Gedeh	52	0.67	(0.46 , 1.00)	0.047
Grand Kru	118	1.08	(0.91 , 1.29)	0.367
Lofa	2,018	0.89	(0.84 , 0.94)	<0.001
Margibi	2,084	1.30	(1.25 , 1.35)	<0.001
Maryland	30	0.96	(0.66 , 1.41)	0.841
Montserrado	11,741	REF		
Nimba	600	1.04	(0.96 , 1.13)	0.338
River Cess	62	0.90	(0.68 , 1.19)	0.455
River Gee	64	0.64	(0.45 , 0.93)	0.018
Sinoe	81	1.07	(0.87 , 1.32)	0.538
Urban/Rural				
Urban	13,172	REF		
Rural	6,221	1.32	(1.28 , 1.35)	<0.001
Unknown	60	0.89	(0.66 , 1.22)	0.480
Phase				
Crisis Recognition	3,650	0.88	(0.86 , 0.91)	<0.001
Emergency	10,853	REF		
Declining Epidemic	4,950	0.22	(0.20 , 0.23)	<0.001
Health Care Worker				
No	9,466	REF		
Yes	606	1.09	(1.04 , 1.15)	0.001
Unknown	9,381	0.44	(0.43 , 0.46)	<0.001
Travel History				
No	5,801	REF		
Yes	597	1.16	(1.09 , 1.22)	<0.001
Unknown	13,055	0.69	(0.67 , 0.71)	<0.001
Hospital Visit				
No	5,417	REF		
Yes	879	0.52	(0.48 , 0.57)	<0.001
Unknown	13,157	0.64	(0.62 , 0.66)	<0.001
Funeral Attendance				
No	6,299	REF		
Yes	723	1.27	(1.21 , 1.34)	<0.001
Unknown	12,431	0.75	(0.72 , 0.77)	<0.001

*RR; Unadjusted relative risk indicating the risk of infection among people with the specified exposure, compared to the risk of infection for all other exposures
CI = 95% Confidence Interval
Phase 4 was excluded from the analysis. Results from the formal reclassification exercise were not available for this dataset, and the case definition changed to include all deaths.

Figure 2-2. Estimated Case Fatality Rate by Age, Liberia, 2014-2016



Smoothed using locally weighted Lowess smoother, for confirmed and probably cases with a date of onset during Phase 1 or Phase 2

Among cases who reported their age, the attack rate was highest among ages 40-49, followed by ages 50-59. Case fatality rate generally rose with age, highest among the 60+ group at 60.3%, and lowest in the 10-19 age group at 38.8% (Figure 2-2). Children under the age of ten were also more likely to die due to EVD. 56.6% of cases were between the ages of 15 and 44. The risk of infection after non-specific exposure was highest among 10-19 years old and lowest in adults over 60.

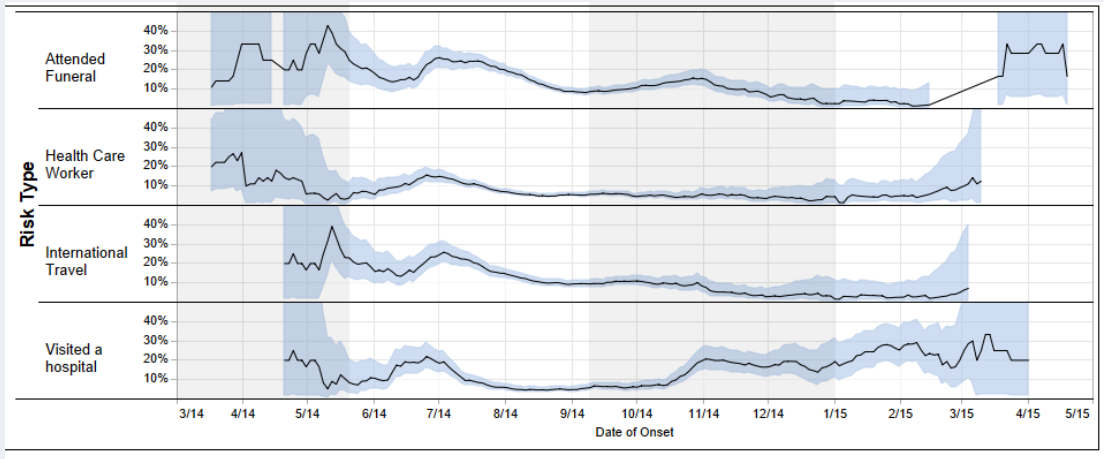
Table 2-6. Variability in ETU case fatality rate, 2015-2016

	Phase 1			Phase 2			Phase 3			Phase 4			Total		
ETU Site	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**	**N**	**Mean**	**SE**
ETU 1	-	-	-	-	-	-	18	55.6	12.1	-	-	-	20	55.0	11.4
ETU 2	322	63.0	2.7	2,225	49.7	1.1	141	42.6	4.2	12	50.0	15.1	2,700	50.9	1.0
ETU 3	-	-	-	33	15.2	6.3	-	-	-	-	-	-	35	17.1	6.5
ETU 4	145	49.0	4.2	76	53.9	5.8	-	-	-	-	-	-	221	50.7	3.4
ETU 5	-	-	-	659	28.5	1.8	91	33.0	5.0	-	-	-	752	29.3	1.7
ETU 6	-	-	-	5	40.0	24.5	36	2.8	2.8	-	-	-	41	7.3	4.1
ETU 7	181	61.9	3.6	156	57.1	4.0	-	-	-	-	-	-	337	59.6	2.7
ETU 8	-	-	-	-	-	-	13	38.5	14.0	-	-	-	18	38.9	11.8
ETU 9	-	-	-	23	87.0	7.2	50	66.0	6.8	-	-	-	74	73.0	5.2
ETU 10	-	-	-	15	26.7	11.8	21	38.1	10.9	-	-	-	41	34.1	7.5
ETU 11	-	-	-	180	41.1	3.7	23	17.4	8.1	-	-	-	206	37.9	3.4
ETU 12	-	-	-	-	-	-	19	63.2	11.4	-	-	-	23	56.5	10.6
Total	**660**	**59.2**	**1.9**	**3,378**	**45.3**	**0.9**	**412**	**39.6**	**2.4**	**18**	**55.6**	**51.1**	**4,468**	**46.8**	**0.7**

*Only for confirmed and probable cases and ETUs with at least 10 cases
Case fatality rate in each phase is only presented if at least 5 cases presented at the ETU. ETU names withheld for privacy.

Case fatality was highly variable between ETUs and phase of the epidemic, as shown in Table 2-6. . Case fatalities in ETUs were highest in Phase 1, and lowest during the declining epidemic in Phase 3. Variability between ETUs in case fatalities was highest in Phase 2, ranging between 15.2% and 87%. Only one ETU operated at scale during Phase 4.

Figure 2-3. Change in exposure type and risk among cases, 2015-2016



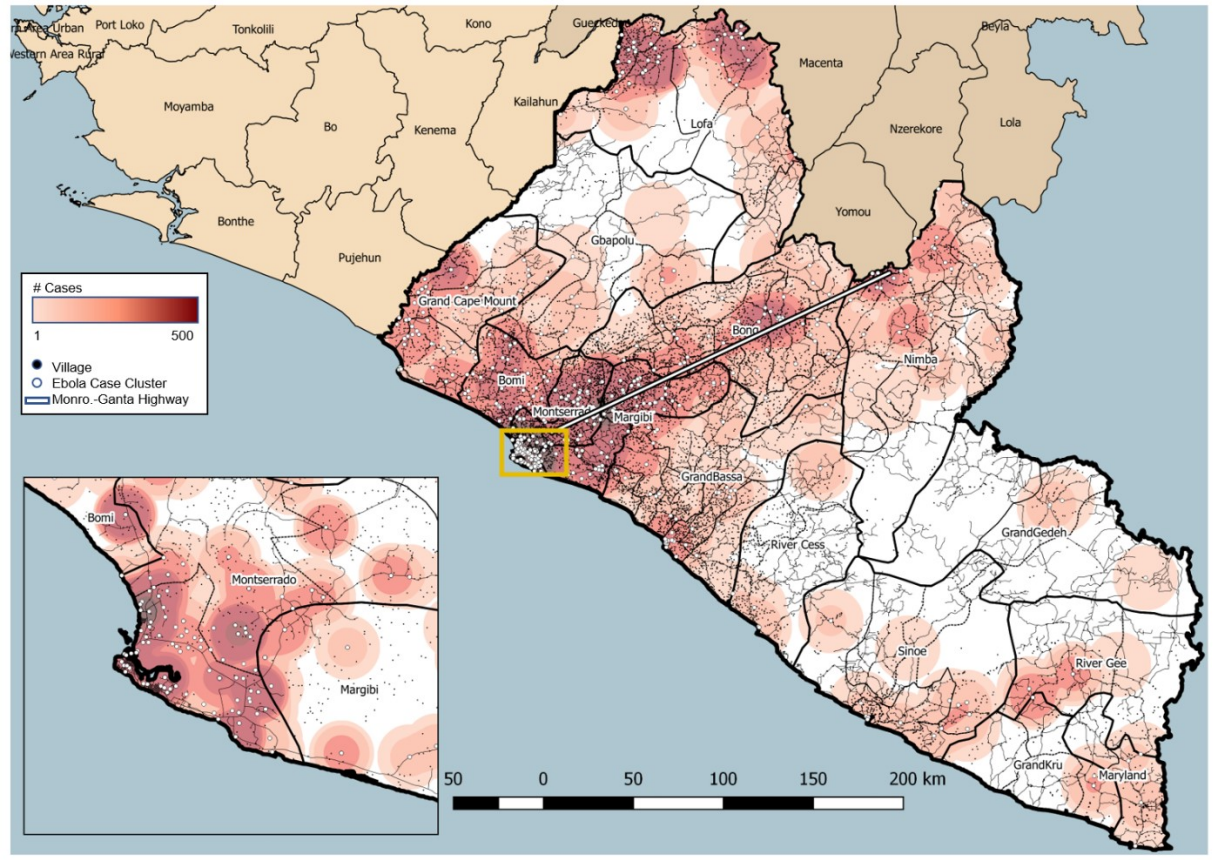
We identified 460 health workers who were EVD cases, 250 confirmed. Health workers had a higher case fatality rate by nearly 10 percentage points compared to non-health workers and were more likely to become infected than individuals with other exposures (RR=1.09; 1.04-1.15). Reports of exposed health workers were highest during the first week of August, accounting for 17% of cases with known health worker status (Figure 2-3). Individuals who reported recent international travel also had higher risk of being a case (RR=1.16; 1.09-1.22). Individuals who reported recently visiting a hospital had lower risk of becoming a case (RR =0.52; 0.48-0.57).

Individuals with a recent funeral attendance had higher risk of becoming a case (RR=1.27; 1.21-1.34). 13% of cases reported attending a funeral prior to the onset of their clinical symptoms. The proportion of cases who reported attending a funeral prior to onset of clinical symptoms reached 40% in May, stabilizing around 20% in August and falling through September to a low of about 10%.

All fifteen counties reported cases throughout the outbreak, though the burden was much less in the eastern region of the country. The overall attack rate was highest in Margibi County (n=1337, AR=5.10 cases per 1,000 population), followed by Montserrado County n=6229, AR=4.47 cases per 1,000 population). Montserrado accounted for over half of all cases, with the largest concentration in the peri-urban areas surrounding Monrovia (Table 2-3). Lofa County, where the outbreak started, accounted for 8% of the final caseload. Lofa County also reported the second highest case fatality rate at 70.3%, second only to River Gee, where most cases were detected through dead body management protocols. Most EVD cases resided in urban areas (69.3%). There was no

difference in case fatality rate between urban and rural areas. Individuals with exposure in rural areas had a 32% higher likelihood of becoming a case compared to urban areas (RR =1.32; 1.28-1.35).

Figure 2-4. EVD Case Density Map, Liberia, 2015-2016

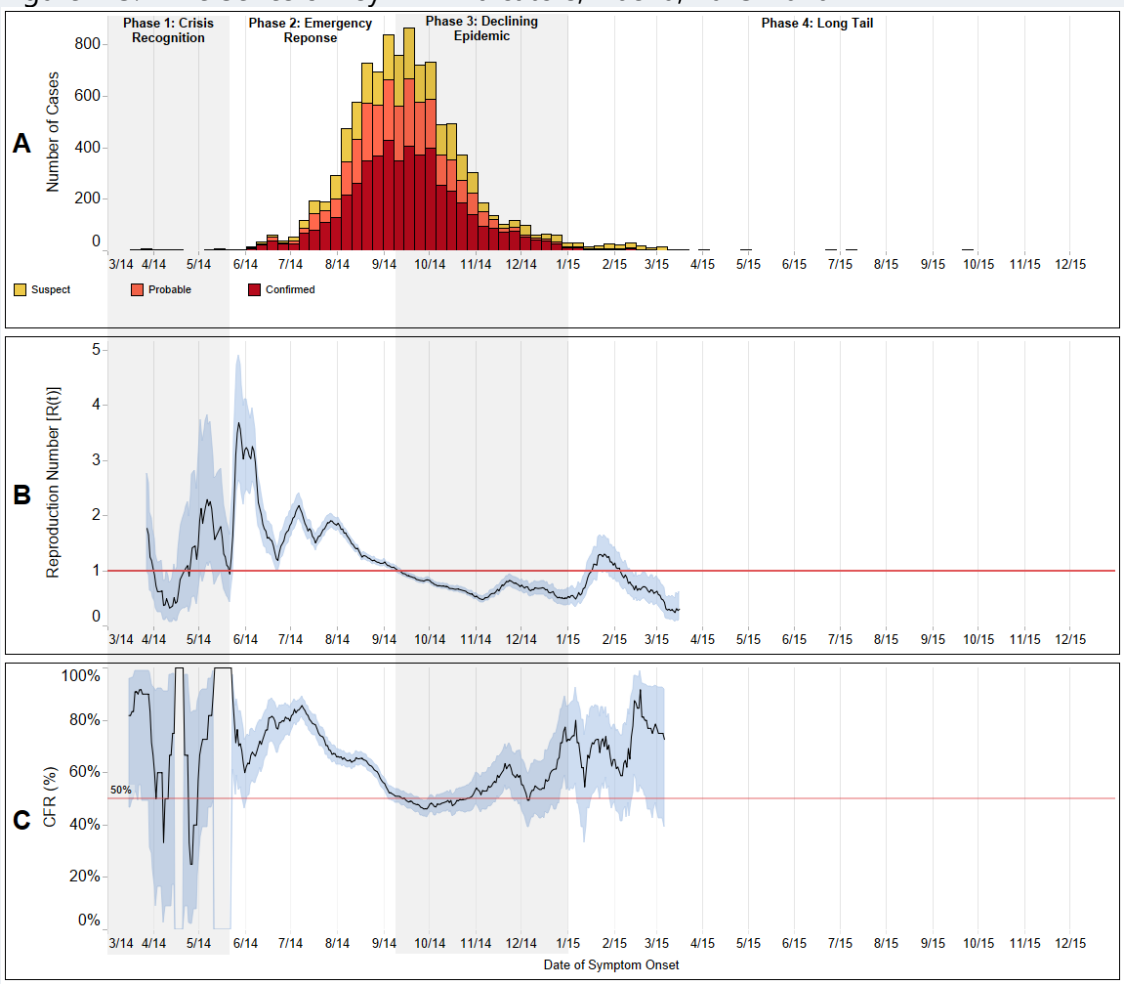


Ebola case clusters refer to a village or town with at least one case

The epidemic map in Figure 2-4 illustrates the case density. The heatmap shows a concentration of cases at the Guinea/ Sierra Leone border in Foya district of northwest Lofa where the outbreak first started. The infection nearly immediately reached in Bomi and Margibi, with the first reported confirmed case in Montserrado in July. It was persistent in Montserrado until the end of the epidemic. The outbreak took hold in the capital Monrovia (shown in the inset), in densely populated communities of New Kru

Town and Gardnersville. Cases were concentrated in downtown Montserrado, especially the Waterside, New Kru town, and Gardnersville communities. Areas of high case density follow general population patterns (Appendix for reference map), spreading across the immediate coastline around Monrovia. Cases were in the comparatively densely populated corridor between Montserrado and Nimba, following the recently constructed highway.

Figure 2-5. Time Series of key EVD indicators, Liberia, 2015-2016



A: Epidemiological curve of suspect, probable and confirmed cases reported per week.
B: Instantaneous reproduction number over a 30 day window
B: Case fatality rate over a 30 day window

Figure 2-5 shows the epidemic curve, instantaneous reproduction number, and case fatality rate for Liberia during the EVD epidemic. We estimate the basic reproduction number, R_0, as 1.72 (95% CI=1.66,1.78). The crisis recognition phase was characterized by a low caseload and large changes in reproduction number as cases reached susceptible urban populations. The initial spike near the end of the phase coincides with an increase in cases in Lofa and the initial introduction of EVD in Montserrado. Case fatality during this phase was high, as access to supportive treatment options was limited and case finding often focused on dead bodies. Average reporting delays early on in this phase stretched upwards of two months, as investigations uncovered epidemiological links which were unknown.

The emergency response phase started with a spike in the reproduction number, overlapping incident cases in Bomi, Bong, Margibi, and Montserrado countries. Caseloads rose exponentially throughout this phase, peaking at 877 cases reported during the first week of September. Case fatality consistently fell during this time, from a peak of about 80% to a low of 40% by mid-September.

The declining epidemic phase started with the instantaneous reproduction number falling below one. CFR reached a low of 41% in mid-October before rising through November. The average delay between the date of onset and report of the case was consistently below one week during this phase.

Figure 2-6. Surveillance system performance indicators, Liberia, 2015-2016

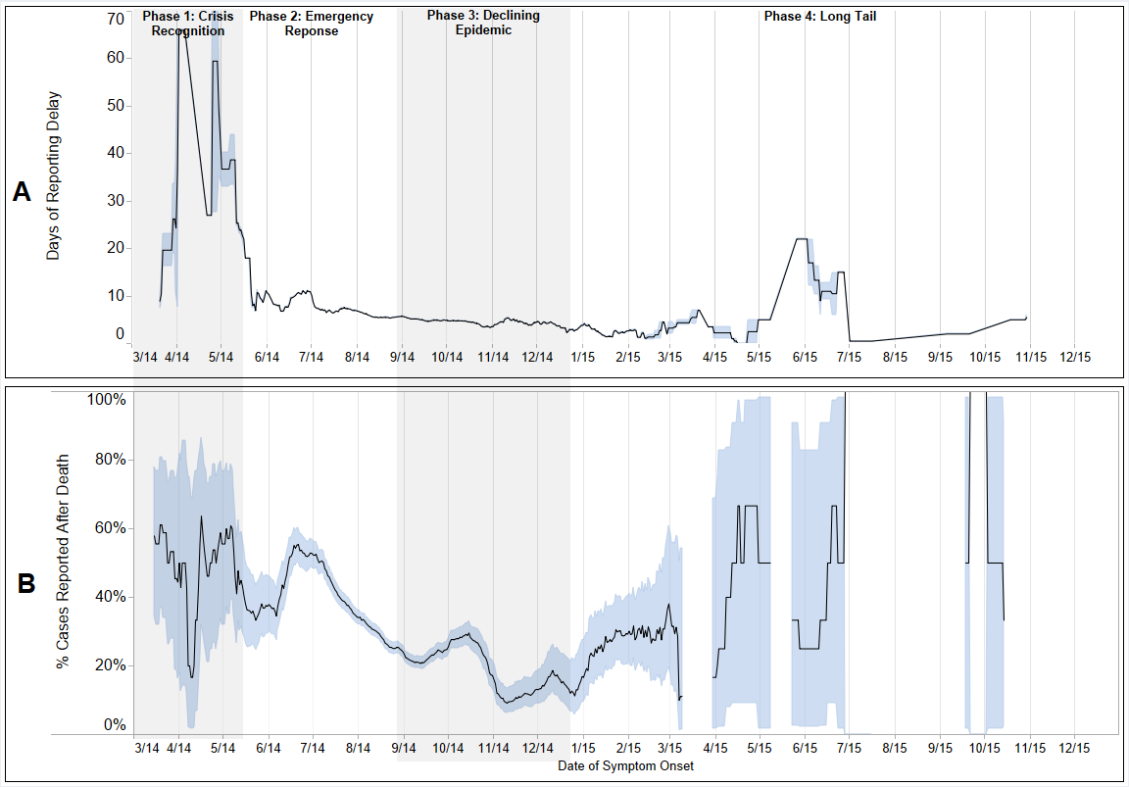


Figure 2-6 shows the performance of the surveillance system in terms of the delay from symptom onset to report, and the proportion of cases reported on or after date of death. A long delay or high proportion of cases reported on or after death indicate a failure of the surveillance system to identify cases in a timely manner to allow for prevention of further human to human transmission. Throughout the long tail in 2015, the focus shifted towards identification and elimination of the final few transmission chains and on general resilience proactive control measures. There were substantial delays in reporting during this time. The average delay between the onset of symptoms and case reporting was 5.31 days (*Poisson* 95% CI 5.24-5.39). About one in three (29.3%) cases were identified after the time of death. This proportion was highest in Phase 1, peaking at 60% and falling through Phase 2, to 10% in November of 2014.

About one in three case fatalities were reported after death. This subset represents a missed opportunity to prevent exposure through isolation and quarantine. We hypothesize that unreported case fatalities were relatively rare for three reasons, (1) deaths are high impact events which are more likely to be identified by the surveillance system (2) dead body teams achieved a high coverage rate, and (3) case finding teams actively searched for sudden deaths due to unknown causes. This assumption is likely more robust in the later stages of the outbreak, when community engagement measures and surveillance structures were in place. However, by adopting the assumption that death reporting is near complete and cases identified at death would not have been reported if they had not died, we can interpolate the late reporting among death statistic into a conservative ballpark estimate of underreporting among convalescent cases. Using these rates of underreporting to adjust the number of convalescent cases, while maintaining the assumption that case fatalities had were not underreported, we arrive at a conservative estimate of 16% underreporting overall, or an additional 1646 cases. Underreporting varies with the proportion of case fatalities reported after death, highest at Phase 1 at 36%, falling in Phase 2 at 26.2%, 18% in Phase 3, and rising to 53% in Phase 4.

Table 2-7. Key Epidemiological Parameters for EVD, 2015-2016

Key Epidemiological Parameters	N	Estimate	SD	Median	Range/ [95% CI]	Range of Past Estimates	Range of Past Ranges
Generation Time (days)	56	13	8	13	0 , 34	10, 16	5.8 , 25
Incubation Period (days)	374	10	7	10	1 , 34	5, 13	1 , 21
Delay from onset to community death (day	2218	10	9	7	0 , 30	6, 10	0 , 34
Admission delay (days)	3881	5	4	4	0 , 174	4, 5	0 , 19
Delay from admission to death (days)	1846	4	4	3	0 , 62	4.6	0 , 20
Delay from admission to discharge (days)	3217	8	7	5	0 , 57	17	0 , 56
Basic Reproduction Number (R0)	910	1.72			[1.66 , 1.79]	1.4, 4.7	1.9 , 5.7
Case Fatality Rate (%)	10280	48.4			[47.4 , 49.4]	69, 88	

Figure 2-7. Illustration of Delays Between EVD Generations

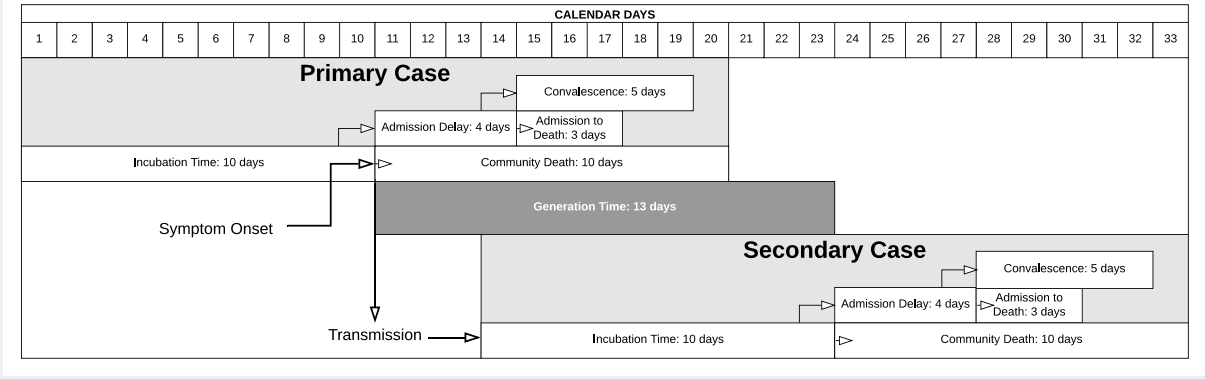
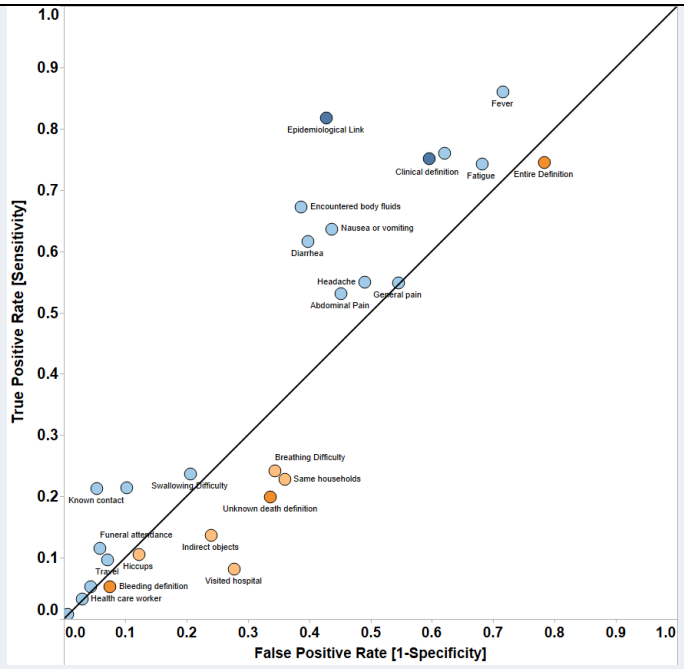


Table 2-7 describes and Figure 2-7 illustrates the estimates of natural history across two generations of EVD infection. The range for each estimate is expected to be larger than past outbreaks, as the extent of the outbreak resulted in data entry or investigation errors which could not be reconciled. The mean for each of these estimates is within the range of previous estimates for EVD outbreaks. The mean serial interval is estimated to be 12.9±7.6 days. This roughly corresponds to previous estimates during this and past outbreaks. A study of Koinadugu District in Sierra Leone estimated the serial interval to be 11.1±5.2 days.[61] The average delay between symptom onset and admission into an ETU was 5.1 ±4 days. This excludes cases which were denied entry into

an ETU due to lack of bed overflow. Once in the ETU, there was an average of 3.8±3.6 days until death, or 7.6±6.9 days until convalescence and discharge. For cases which were not admitted into an ETU, convalescence was not measured. The average duration until community death was 12.9 days.

Figure 2-8. Diagnostic power of known exposures, signs, and symptoms, 2015-2016

Criteria	Sensitivity			Specificity			Positive Predictive Value			Negative Predictive Value		
	N	x̄	SD	N	x̄	SD	N	x̄	SD	N	x̄	SD
Entire Definition	4843	0.74	0.01	2681	0.22	0.01	13984	0.45	0.00	10098	0.61	0.00
Clinical definition	4032	0.75	0.01	2150	0.40	0.01	13929	0.47	0.00	11495	0.61	0.00
Fever	4032	0.86	0.01	2150	0.28	0.01	14625	0.48	0.00	10799	0.62	0.00
Nausea or vomiting	3972	0.64	0.01	2119	0.56	0.01	13165	0.46	0.00	12350	0.59	0.00
Diarrhea	3971	0.62	0.01	2123	0.60	0.01	13000	0.46	0.00	12512	0.59	0.00
Fatigue	4730	0.74	0.01	2263	0.32	0.01	13863	0.46	0.00	10750	0.63	0.00
Loss appetite	3939	0.76	0.01	2125	0.38	0.01	14051	0.47	0.00	11491	0.60	0.00
Abdominal Pain	3867	0.53	0.01	2101	0.55	0.01	12833	0.45	0.00	12805	0.57	0.00
Headache	3910	0.55	0.01	2103	0.51	0.01	12967	0.45	0.00	12626	0.57	0.00
Breathing Difficulty	3804	0.24	0.01	2082	0.66	0.01	11555	0.40	0.00	14165	0.53	0.00
Swallowing Difficulty	4699	0.24	0.01	2218	0.79	0.01	10457	0.38	0.00	14232	0.55	0.00
Hiccups	3721	0.10	0.01	2047	0.88	0.01	10675	0.39	0.00	15163	0.53	0.00
General pain	4783	0.55	0.01	2406	0.45	0.01	12546	0.43	0.00	11871	0.59	0.00
Epidemiological Link	1743	0.82	0.01	841	0.57	0.02	15004	0.48	0.00	14018	0.56	0.00
Known contact	7540	0.21	0.00	8263	0.95	0.00	2045	0.78	0.01	13758	0.57	0.00
Health care worker	5121	0.05	0.00	2862	0.96	0.00	8212	0.33	0.01	15411	0.53	0.00
Funeral attendance	3160	0.12	0.01	2526	0.94	0.00	10632	0.45	0.00	15288	0.53	0.00
Travel	2918	0.10	0.01	1967	0.93	0.01	11338	0.43	0.00	15383	0.53	0.00
Visited hospital	2773	0.08	0.01	1955	0.72	0.01	11842	0.42	0.00	15036	0.51	0.00
Visited traditional healter	1664	0.03	0.00	199	0.97	0.01	14001	0.42	0.00	15742	0.52	0.00
Animal contact	1864	0.01	0.00	210	1.00	0.00	13744	0.41	0.00	15788	0.52	0.00
Encountered body fluids	378	0.67	0.02	838	0.61	0.02	15165	0.49	0.00	15225	0.52	0.00
Physical contact	346	0.21	0.02	782	0.90	0.01	14829	0.49	0.00	15649	0.52	0.00
Indirect objects	22	0.14	0.07	50	0.76	0.06	15746	0.48	0.00	15788	0.52	0.00
Same households	22	0.23	0.09	50	0.64	0.07	15754	0.48	0.00	15780	0.52	0.00
Bleeding definition	4671	0.05	0.00	2169	0.93	0.01	9370	0.33	0.00	15396	0.53	0.00
Unknown death definition	4843	0.20	0.01	2681	0.66	0.01	10145	0.36	0.00	13937	0.53	0.00

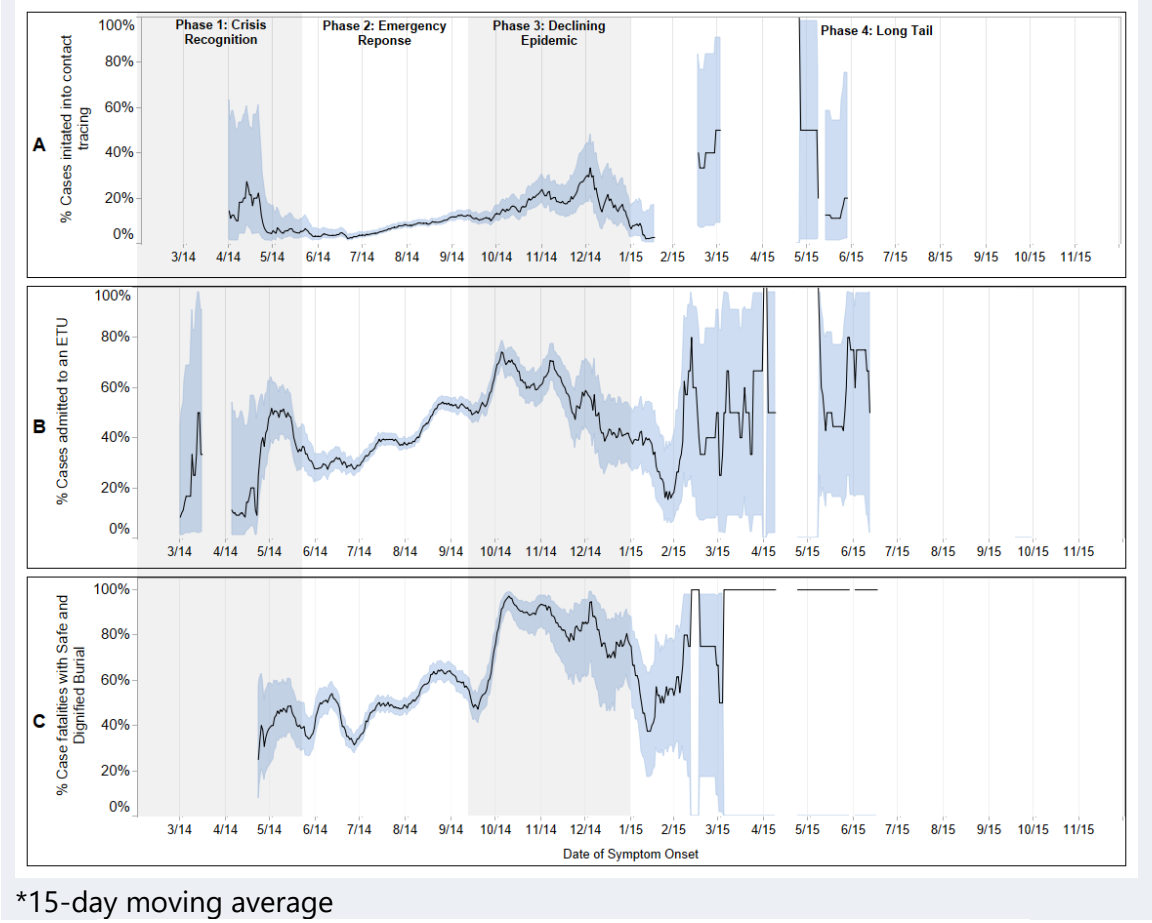


Green circles depict criteria which fall above change, and orange circles denote which fall below chance. Larger circles are the criteria which were part of the suspect case definition. Data are taken from Phase 2 and 3. Phase 1 is excluded to account for poor training among investigation staff which may lead to misclassification, and Phase 4 is excluded as the suspect case definition was changed to include all deaths.

Four in ten (40.0%) individuals had data for all elements of the suspect case definition. For cases with unknown cause of death, sensitivity was 15%, and specificity 88%. For the expanded suspect case definition (Table 2-1), 45% of cases and 55% of non-cases met the criteria. The sensitivity was 74%, and specificity was 22%, falling below the random guess benchmark (slanted line) on the ROC diagram in Figure 2-8. This indicates the overall power of the suspect case definition similar to the efficiency of a random guess.

Figure 2-9 illustrates the coverage of contact tracing, ETU, and burial interventions among eligible cases. Contact tracing coverage peaked in December 2014, as the last transmission chains of the main epidemic were being tracked. Though contact tracing generated many contacts and was a crucial element of tracking transmission chains in elimination effort, only a small proportion of cases had initiated contact tracing. Coverage of contact tracing was 8.6% among all cases and 11% among cases in Montserrado County. A poor match rate between sources and cases due to the lack of information collected on the sources may depress the numbers from the true estimate. Under the assumption that all 1947 reported sources were cases, the maximum possible coverage of contact tracing in Montserrado is 31.3%.

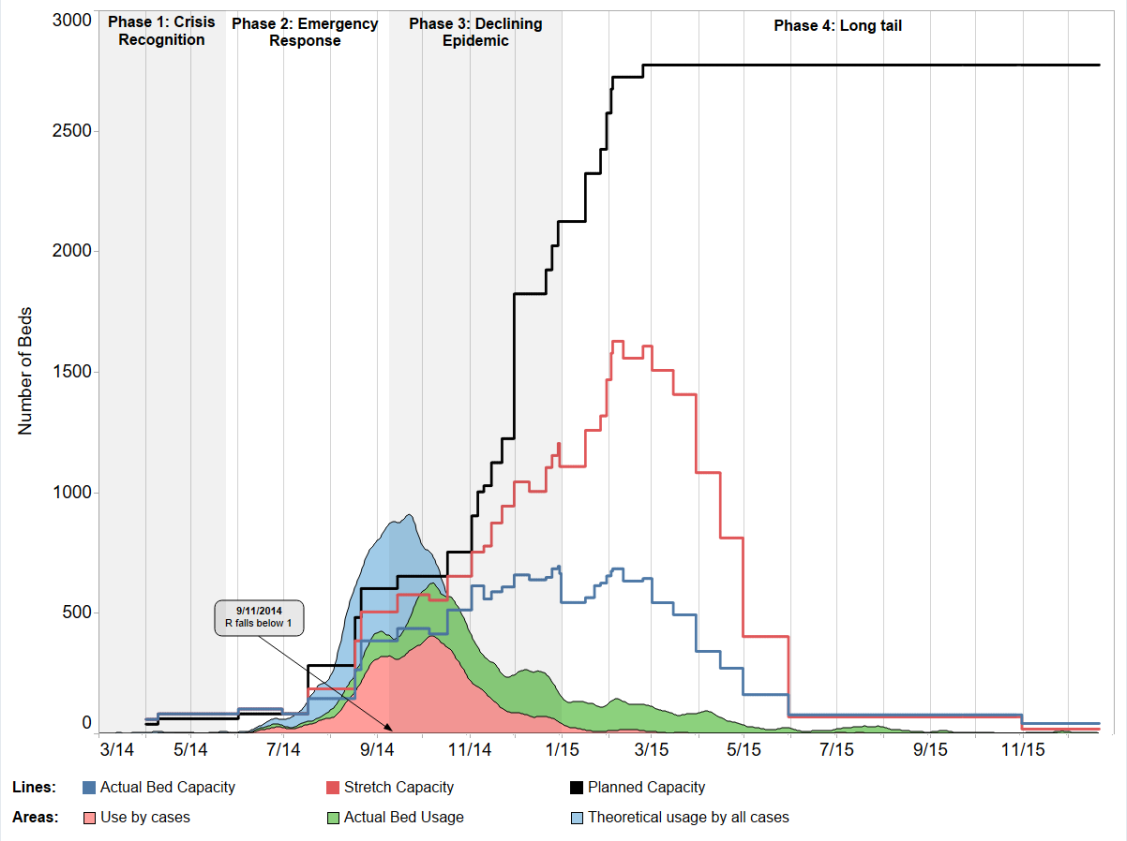
Figure 2-9. Percentage of EVD Cases participating in control measures



*15-day moving average

Approximately 2 in 3 cases (66%) were buried following proper infection prevention standard. Dead body management peaked in early October at 94% of cases. We estimated that 43.0% of cases had an ETU admission. At the peak in November three-in-four cases were admitted into ETUs. There was a coverage peak in April, driven by the ETU management by MSF and Samaritan's Purse. ETU building spiked in November, with 7 ETUs built around the country, more than doubling the existing number. The building continued through January, as the US military completed their planned facilities, with two facilities built in December, and six builds in January. Though there were many ETUs built in November 2014, however, usage fell through the month as cases left, and new cases being identified were often reported at the time of death

Figure 2-10. ETU Capacity and Bed Usage



We estimate planned ETU construction would have made available 2,775 beds during the epidemic. Demand for ETU beds outpaced supply during the emergency response and start of the declining epidemic phases. Most construction occurred after bed usage began to fall in early October 2014. Due to the reduction in usage, many of the planned ETUs were canceled or scaled down in staffing and equipment to support less than a tenth of the original patient population, with the ability to stretch capacity.

Peak usage was on October 10th, 2014, at 574 beds in use, corresponding to the peak observed in case coverage in Figure 3-5. Bed capacity peaked at 695 on December 29th, 2014, with a peak stretch capacity of 1629 on February 5th, 2015, coinciding with the end of the mission for the US military's Operation United Assistance.

Bed availability and ETU construction was assessed nationally. Gaps in capacity may have existed for longer periods in high burden areas such as the capital city of Montserrado. In Montserrado, ETU usage exceeded capacity at the start of October and maintained stretch capacity levels for the entire month before falling. (not shown).

2.5 DISCUSSION

The outbreak in Liberia was part of the longest and largest known EVD outbreak to date. Case reclassification and deduplication of the surveillance dataset resulted in a lower case estimate than presented in the official situation reports.[9] We estimate between March 1st, 2014 and December 31st, 2015, infection with EVD had been confirmed in 5110 individuals in Liberia, with a total of 10,280 suspect, probable, and confirmed cases. A substantial portion of transmission may have gone undetected and the actual burden of disease is likely higher. Reports of asymptomatic and minimally symptomatic patients during the outbreak which may have not met the standard case definition, and poor trust in the health system may have repressed identification in some communities.[62,63] Further, some cases may have been misclassified as non-cases due to poor case-finding and use of non-standard case definitions; for instance, there were reports of investigators and contact tracers using lack of fever as a *de facto* exclusion criteria.[44] Our conservative estimate of underreporting suggests an actual case burden of 11,934 cases, a 16% underreporting rate. This estimate is lower than a reported district specific underreporting in Sierra Leone between 33% and 68% in October 2014, falling to 18% in March 2015, but corresponds well to an estimated 24% underreporting in Montserrado during Phase 2 (compared to 26% during the same period using our

method).[64–66] This method of ballparking underreporting using readily available surveillance data may be useful in similar settings and high mortality outbreaks, but may perform worse in outbreaks in rural areas where entire transmission chains in some communities may remain undetected. Further exploration of reporting rates and their effect on the spatiotemporal dynamics of Ebola during this epidemic are warranted.

The match rate is much lower than expected between some databases. For instance, the low match percentage between source cases and the DHIS line list suggests sources were not reliably identified and reported. The low match rate between ETU records and the DHIS line list suggests poor communication between ETUs and case investigation teams. These issues may have prevented accurate estimation of cases in real time during the epidemic, or could be a byproduct of data quality and lack of personally identifiable information in some datasets.

Ideally, cases would be soon after symptom onset through contact tracing or other means of identification. The median report delay was four days after the date of onset, with 75% reported within one week. The report delay was similar to the admission delay, and many cases were identified only when they presented to the ETU rather than by active case finding. The reduction in delay after Phase 1 is a testament to both the improvements in the organization of leadership and strengthening of surveillance structures during emergency response.

Contact tracing was initiated for 8.7% of cases and proactively identified 378 cases. This proportion may be higher when accounting for a low match rate between contact tracing and case data, and difficulties in collection and digitization the paper

records.[67] However, the maximum hypothetical coverage is 23%, assuming all individuals with initiated contact tracing activities were EVD cases. Lack of resources is likely not a driver of this low rate. As an example, the St Paul River cluster was one of the last known clusters assumed to have originated through indigenous transmission, and had ample human, technical, and financial resources to trace contacts. However, one-third of cases in the cluster were never tracked through contact tracing.[44] Community avoidance is likely a larger contributory cause, the mandatory cremation and property destruction reportedly caused cases and contacts to avoid participation in investigations.[68] Overall, the proportion of cases with initiated contact tracing rose over time, reflecting the reliance on contact tracing as a tool to interrupt transmission chains late in the outbreak. Contact tracing remains an integral disease control measure to prospectively identify cases (epidemiological linkage was the best performing classifier of EVD cases) and prevent secondary transmission (in the St. Paul cluster, all cases in the final generation were tracked as contacts and isolated). However, further work is needed to improve documentation, community engagement and compliance, and coverage of these activities.

A difficulty in discriminating between cases and non-cases may have added to the performance deficits in the surveillance system. We estimate the sensitivity of the WHO expanded suspect case definition performed slightly inferior to a random guess. The definition did perform at a similar level to the outbreak in Guinea (sensitivity 68%, specificity, 49.7%) and better than the simplified case definition published in 1999, (sensitivity 58%, false negatives >30%).[69,70] The change towards an expanded case

definition was in response to the poor availability in epidemiological and clinical information for many cases, and the late presentation of highly specific hemorrhagic symptoms. Of components of the suspect case definition, evidence of an epidemiological linkage and fever was the best performing classifier. Despite the concern that using early clinical signs would result in the misclassification of cholera and malaria as Ebola; fever, diarrhea, and nausea/vomiting were the best performing symptom classifiers, and the overall clinical definition performed better than chance. Symptom data were collected at the time of report for most cases, and such classifiers may change in performance dependent on the reporting delay and clinical course. We expect this is the cause of the relatively poor performance of the hemorrhagic symptoms of the case definition, as cases were reported before the onset of full hemorrhagic signs such as hematemesis. Overall, though the expanded case definition is advantageous for the paucity of information availability during an active outbreak and severely reduces the false negative rate, improvements are still needed. There is a moral imperative to minimize false positives. Case teams will often refer suspect patients directly to ETUs (or the patient may self-refer) where there may be a chance of transmission to false positives. Improvements to the suspect case definition do not necessarily require a redefinition. Instead, surveillance teams can emphasize collection of the classifiers with the most predictive power to increase the information available for the discrimination, and preferentially use the epidemiological linkage component when data for multiple components are available. This definition is also only useful when an outbreak has already been confirmed. Both in this outbreak and previous outbreaks, initial identification of Ebola

was delayed by misclassification as Cholera, or bloody diarrhea mistaken for Shigellosis.[71] Field diagnostics and laboratory support will be integral in early identification, and confirmatory testing to continue to refine case and clinical definitions.

Availability of epidemiological parameters estimates from previous *Ebola Zaire* outbreaks is limited. We reproduce a selection of these parameters from a comprehensive review by Kerkhove et. al. (2015) in the supplement in Table 7-2.[72] Our estimates for serial interval, incubation period, R_0, and range of values for R_t were within the range of these previous estimates, though the R_0 is the second lowest reported to date (the first being an outmoded modelled estimate of R_0 for outbreaks in Congo and Uganda) and case fatality was much lower than previously reported. The admission delay was also similar to previous outbreaks, and the delay between hospitalization and death or discharge were slightly lower.[73] The delay between symptom onset and death was roughly three days higher in Liberia, though previous studies did not constrain this estimate to only cases which did not visit an ETU. The apparent similarity in epidemiological parameters and clinical time course between this outbreak and past outbreaks of EVD indicates that the severity of the West African outbreak was not due to a fundamental change in disease transmissibility, virulence, or access to treatment. The remaining differentiation is then context. The outbreak in West Africa reached urban centers, vastly increasing the exposed population, and eventually resulting in a caseload which was unmanageable by the existing disease surveillance and control structures.

Our estimate of the basic reproduction number was slightly higher than previous estimates of 2014-2016 West Africa outbreaks, and on the lower end of estimates for

EVD in previous outbreaks.[73–75] The reproduction number is a function of the effective contact rate, and not a biological constant. The effective contact rate will change based on social determinants, political and structural context, population structures, and seasonality. Past outbreaks were much smaller, and may have contained a higher proportion of superspreading (high transmission) events. Though case clustering has been demonstrated during this epidemic, it is possible the spread to urban areas in this outbreak reduced the reliance on superspreading to sustain the infection in the population, and lowered the overall number of secondary cases.[64] This effect may be masked even when stratifying the basic reproduction number by population density, due to high mixing between urban and rural areas. Further investigation into the extent and impact on transmission of superspreading effects is warranted.

We show a variation in the instantaneous reproduction number, which may be indicative of the outbreak reaching new populations or high transmission funeral events. Our estimate of when the reproduction number first crossed below 1 is mid-September. Correcting for underreporting based on the proportion of cases reported after death did not significantly change the instantaneous reproduction number over time, though there may be spatial patterns which we did not investigate. We detected a brief resurgent period in late January, as hidden transmission chains were discovered in Bong and Montserrado. The overall decline in the instantaneous reproduction number correlates with the reorganization of response and leadership following the creation of the IMS. However, we cannot draw a clear consensus on the marginal impact of control measures.

Early response measures emphasized the importance of EVD treatment centers, spurred by estimates of 70% ETU coverage needed to halt the epidemic.[76] While ETUs may have helped control the outbreak, the reproduction number and caseload were both declining before the major ETU buildup and well before this coverage threshold was reached, suggesting the epidemic was already within control. Most additional treatment bed capacity was built outside Montserrado. By the last week of August, Montserrado had a capacity of 423 beds. The ETU presence was still likely pivotal in managing dead bodies and reducing funeral and community exposures. ETUs managed about 30% of dead bodies, and 43% of all cases recorded an ETU admission.

Case fatality changed significantly over time. We hypothesize the high case fatality in phase 1 is due in part to preferential reporting of deaths and lack of treatment access and knowledge. There was a minimal 3% reduction in case fatality for cases in the ETU, and significant heterogeneities in case fatality between ETUs. The small magnitude CFR reduction may be driven by the overcapacity and under-resourced nature of ETUs during the peak of the epidemic. ETUs in urban areas with high caseload exceeded stretch capacity, and there were reports of patients treated on the floors between beds.[77] Some ETUs offered only oral rather than parenteral rehydration partially due to fears of health worker exposure.[78] ETU morgues stowed dead bodies from the community, which may have been falsely included in ETU admission registers. There is also the possibility that patients delayed seeking treatment until late in clinical course where supportive treatment had limited effect. For instance, the initial admissions at ELWA were critically

ill, and had been waiting outside the ETU for care.[52] However, treatment delays were not found to be significant in a multi-country study of the outbreak.[79]

Overall, case fatality during the outbreak was much lower than previous EVD outbreaks.[80] This finding persists even when excluding suspect cases and records missing outcome information (instead of assuming they are alive), which would increase CFR to 58.4 [57.2-59.6]. The decrease in case fatality may be due to improved case finding of convalescent cases, different underlying risk of death in the infected Liberian population, or a general increase in knowledge of supportive care. It is also possible that deaths occurred after the conclusion of the case investigation but were never reported. It may be possible to improve outcomes further by accounting for heterogeneities in case fatality rate by age; such as prioritizing parenteral rehydration among children under 10 years and adults over 60 years of age as recommended in supportive treatment guidelines.[78]

Interpretation of risks of infection is complicated by selection and reporting biases. Risk information may have been preferentially collected for cases with at least one known risk at time of report. Further, recall of point exposures such as funeral attendance within a suitable timeframe may be limited. For exposures such as international travel, the increase in risk of infection may be tied to other causes, such as a higher occurrence of fever among travelers, rather than an increase in EVD transmission. Despite these limitations, cases with a funeral exposure had a 27% higher risk of becoming an EVD case compared to those with other exposure types, providing further evidence for funeral attendance as a primary driver of transmission. This heterogeneity in

risk of infection provides suggestive evidence for potential superspreading events discussed in other papers.[81] The proportion of cases with funeral exposure decreased through Phase 2 and 3, before increasing again. We could not say for certain if these exposures included unsafe handling of the body or exposure to bodily fluids. It is likely the reduction in the proportion of cases with a funeral exposure was fueled by the cremation directive, whereas the subsequent increase in funeral exposure corresponded with the policy shift towards safe and dignified burials.

We were not able to directly measure the impact of community engagement and behavior change using surveillance data. The increase in coverage of control measures can be, at least in part, attributed to tackling hesitancy and mistrust in the community. This implies in addition to a direct decrease in exposure, community engagement and increasing trust can have a multiplicative effect in adherence and participation in other control measures.[82] Community health workers can act as bellwethers to future emerging diseases. Long term resiliency to future health emergencies will depend on communities and the health system to be well prepared and in lockstep; including a joint discourse on health priorities, engagement through programs such as community event-based surveillance, and open and transparent communication.

2.5.1 Limitations

Surveillance data have several natural limitations. Data may be incomplete, and there is evidence of under-reporting which were not able to directly estimate. During the data retrieval, some county surveillance officers and ETU operators reported destroying forms due to fears of contamination.[67] Under-reporting of specific variables of interest

increased during the peak of the outbreak when the health system were strained to respond and document the rising incident cases. Under-reporting is likely to be prevalent in rural areas, where the logistical barriers in reporting a case to the national, access to health facilities are limited, and stigma from the outbreak may have suppressed the identification of transmission chains.

2.6 CONCLUSIONS

The 2015-2016 EVD outbreak in Liberia had a similar epidemiological parameter and delays as previously reported outbreaks. We propose the exceptional nature of the outbreak was not driven by a fundamental change in transmission patterns, but a combination of the outbreak reaching dense population centers, and health systems which struggled to rapidly identify transmission chains and implement sophisticated non-pharmaceutical control measures. Community engagement, resulting changes in approach to dead body management, and a reorganization of response leadership coincided with a reduction in transmissibility, whereas additional ETU treatment capacity arrived after the reproduction number fell below zero. We find further suggestive evidence that funeral exposure was a primary driver of transmission, with 27% greater risk of infection compared to all other exposures. Case fatality was among the lowest of past EVD outbreaks, and we did not observe a significant impact of ETUs. There was a large variability in case fatality between ETUs, which may be due to differences in treatment as well as role in outbreak response. The outbreak posed a major challenge to the weak disease surveillance system in Liberia, however challenges are not unique to EVD. Emerging respiratory diseases with higher rates of transmission pose an even

graver risk, and steps must be taken to improve the overall resiliency of the health system to future emerging disease.

3 Implementation and Sustainability of a Community Event-Based Surveillance Pilot in Liberia

3.1 Abstract

Background: Following the 2014-2016 West African EVD outbreak, the Ministry of Health in Liberia and the International Organization for Migration implemented a Community Event-Based Surveillance (CEBS) program in 8 counties and 2972 communities to aid in early detection of priority diseases and conditions. CEBS is a specialized referral activity involving the collection of information on events of public health concern in the community and by the community. Community surveillance workers were trained to refer community members based on twelve syndromic community case definitions. In this analysis, we review the implementation of CEBS and evaluate the sustainability of its activities as Liberia transitions from emergency response to routine disease surveillance.

Methods: We conduct a retrospective review by comparing disease reports in 2016 from the Integrated Disease Surveillance and Response (IDSR) surveillance system to reports of triggers from the community to calculate coverage and positive predictive value of each community case definition. We also conduct a document review based on in-depth interviews, observations from technical group meetings, key informant interviews, and an interviewer administered survey to describe the program implementation, community surveillance workers (CSWs), and characterize the sustainability of the program in Liberia.

Results: Between February 2016 and October of 2016, the program detected 3746 alerts resulting in 885 suspect cases. Approximately 31.5% of non-EVD cases in the national surveillance system in the program areas originated from CEBS reports. Over 95% of reported alerts met the community trigger definition, and 885 ultimately met the case definition of an epidemic-prone disease and were reported to the district level for further investigation. The positive predictive value was highest for reports of neonatal, maternal, and unexplained death, and lowest for rare diseases (VHF, meningitis, and AFP). Recall of triggers was highest for acute watery diarrhea, and the most popular source of information was house to house visits and general word of mouth. Transportation between the community and health facility was reported as a major barrier at all levels. Across the domains of sustainability, we find mixed evidence for the domains of partnerships and program adaptation, and severe limitations in the domains of organizational capacity and funding stability. As designed, the program accounts for 19.4% of government expenditure on health. We estimate cost reductions and integration with existing community initiatives would reduce this to 2.9% of government expenditure on health. Coupled with a transition towards a more community-driven or routine program these cost reductions may result in a more sustainable model.

Conclusions: We classify the structure and goals of the CEBS pilot in Liberia align most closely with an active response design and suggest it is unsustainable in its current form due to challenges in organization capacity and financial sustainability. Transportation barriers and poor recall of rare conditions limit the use of the program for early detection of epidemics in remote communities. However, a substantial proportion of

reports in program areas originated through CEBS, and the program was effective in extending the range of the surveillance system to remote areas and in engaging the community in reporting epidemic-prone disease. We suggest that if community surveillance programs in Liberia and other resource-limited settings are to succeed, program goals should closely align to available capacity, barriers to reporting be proactively addressed, and selection of diseases to monitor be carefully considered in relation to context.

3.2 INTRODUCTION

In 1995, the International Health Regulations (IHR) were updated, coming into force in 2007 as a legally binding agreement with 196 state signatories aimed at preventing the international spread of disease. IHR intended to mobilize improvement in the detection of emerging infectious disease (EID) by promoting local and global disease surveillance and response capacity.[83–85] In the African region, Integrated Disease Surveillance and Response (IDSR) provides a framework for low-income countries to build real-time surveillance, supplementing existing aggregated facility-based reporting which are less sensitive and responsive to disease trends.[86]

Through the implementation of IDSR, the region is building a core capacity in syndromic surveillance by through community-event based surveillance (CEBS) programs to provide early warning of cases of public health importance, mobilize response, and reduce morbidity and mortality within the population.[87] A 2019 WHO panel defined community-based surveillance as "the systematic detection and reporting of events of

public health significance within a community by community members".[88] CEBS is defined in Liberia as the "organized and rapid collection of information from community events which are a potential risk to public health."[89,90] CEBS shortens the delay in disease detection by extending the surveillance apparatus into communities by training community members on simplified syndromic triggers.[90]

We focus here on the implementation and sustainability of the Liberian CEBS program, a community-level disease reporting activity which provides early warning and response to health events. For this assessment, we define sustainability as "after a defined period, the program…continues to be delivered…and may evolve or adapt while continuing to produce benefits for individuals/systems" as proposed by Moore et al. (2017).[91] The objective of this paper is to discuss factors which influence sustainability and propose a typology for community surveillance programs, based on lessons learned during the design and implementation of a community event-based surveillance program based in Liberia following the 2014-2016 West African EVD outbreak.

3.2.1 Overview of Community Disease Surveillance

CEBS programs are abstract and poorly defined, resulting in a large variety of formulations and little consensus on best practices.[92] Traditionally, CEBS activities are leveraged for diseases targeted for elimination or eradication (e.g., avian influenza, polio, and guinea worm) intending to increase sensitivity an coverage of disease detection in remote regions.[93–101] Activities for these often siloed, narrowly targeted, and vertical programs, range from reliance on passive detection to blanket coverage through costly household surveys. The introduction of IDSR encouraged a shift from vertical to

integrated disease surveillance. Programs integrating multiple epidemic-prone diseases into a single reporting platform have piloted in regions of India, Ghana, Cambodia, and Ethiopia.[102–105] These are distinct from the more common community information systems which do not collect detailed event information, but instead aggregate counts of disease over a period of time. Aggregate reporting can hide individual and community level variation and lack the information needed to initiate case investigation or assess the severity of disease. Less formal programs have involved volunteers participating in monthly community discussions on health problems in Latin America, or identifying mosquito larval vectors in Tanzania.[106,107]

CEBS also provides advantages over traditional facility-level surveillance methods, apart from increasing the coverage and sensitivity of disease surveillance. The program improves linkage to care especially in geographies where travel time to the nearest health facility can be measured in days. This is especially useful with diseases with clear prodromes and unmet need. The use of pre-diagnostic syndromic triggers creates rich datasets capable of producing risk maps and identifying patterns of unknown causes of disease and death. For communities, it provides a platform to participate in disease surveillance and realize rights affirmed in the Alma Atta declaration.[108] Engagement of communities facilitates risk communication through continuous dialogue, provides a democratic voice to surveillance system governance, and more efficient collaboration during epidemic response.[109,110] Training communities in disease surveillance may lead to genuine empowerment.[111,112]

The data generated from CEBS programs can be used for risk analysis of population disease burden and hotspots, in addition to immediately actionable responses to identified cases. These programs can generate a large amount of information, which can be challenging to synthesize. Often, the limited data analysis resources in low income countries may be dedicated to routine analysis of traditional disease surveillance sources. CEBS data may overlap with pre-existing routine information systems such as Liberia's Community Based Information System (CBIS). The aggregate indicators in the routine system are less responsive to emerging threats and do not provide real-time information. The two can be complementary, however, as routine information systems can provide a more comprehensive view of community health, provide baselines, and monitor long term trends.

3.2.2 Concepts of Sustainability Applied to Community Disease Surveillance

CEBS programs are difficult to sustain, evidenced by evaluations of IDSR which consistently cite community engagement as a major weakness.[113–115] Community programs tend to conclude with their funding periods; host countries struggle to continue the activities.[116] Short funding horizons exacerbate the situation, requiring developing countries to achieve sustainability of complex programs in rapid timeframes.[117]

The range of motivations for community participation in surveillance leads to similarly diverse definitions of program sustainability. Past programs have featured defined time horizons and targets of elimination, or are judiciously limited to geographies where community surveillance be most impactful.[93] As with many

community interventions, CEBS requires a significant initial investment. Human, financial, and organizational capacity are needed to manage and translate the large amounts of data.[116] The loss of this investment, and the disillusionment and disengagement of the community when the benefits are removed, are a strong motivator for sustaining the benefits.[116]

There are various frameworks which explore programmatic sustainability for different levels of operation, contexts, actors, and timeframes.[118,119] The most comprehensive was proposed by Shediac-Rizkallah and Bone (1998) which consists of three indicators of sustainability;

(1) continued health benefits for individuals,

(2) institutionalization or routinization of program activities, and

(3) continuing development of community's capacity to deliver the program – applicable when the program is delivered through community structures.[116]

The determinants which influence sustainability were proposed as

(1) factors in the broader community environment,

(2) project design and implementation factors, and

(3) factors in the organizational settings.[116]

This concept was further extended in the Dynamic Sustainability Framework (DSF) which emphasizes change over time in both the intervention and setting.[120] Consequently, sustainability is not explored at a designated point during the program life cycle, but a process which is concurrent with program implementation.[121]

Focusing on communicable disease surveillance programs, Shigayeva and Coker (2015) propose five precursors to sustainability: leadership, capacity, flexibility/adaptability, interactions, and performance.[122] The concept of 'interactions' describes the adaptation of the intervention to its setting as a range of institutionalization which occurs within each of the building blocks of the health system. The natural setting for community disease surveillance as an enormous impact on the sustainability of the program, as different cultural norms, burdens of disease, and health systems modify the effectiveness and sustainability of activities. Iwelunmor et al. (2015) propose combining the DSF with frameworks on cultural models to better explain the idiosyncrasies of sustainability in sub-Saharan Africa.[123]

Analogous to sustainability, the concept of "scaling up" is particularly significant for CEBS programs. Due to the large initial investment, many community disease surveillance programs begin narrowly defined in disease focus, geographic footprint, operational scale, or timeframe. Subramanian et al. (2011) propose factors for success scaling from existing frameworks similar to those identified above but also argues this sort of reductionist approach is biased towards supply-side factors, and ongoing 'learning by doing' approaches are more likely to result in sustainable programs than prescribed blueprints.[124]

Paina and Peters (2012) propose viewing scaling and sustainability through the lens of a complex adaptive system, which takes into account the feedback loops, time dependencies, unintended effects, path dependencies, and networks characteristics of programs.[125] This viewpoint complements the more simplistic models by advocating a

deeper understanding of the pathways of change, taking into account the peculiarities of the setting. An example of an application of this viewpoint is the Develop-Distort Dilemma, which can help detect and avoid unintended effects, such as alienating traditional health providers who may be resistant to the loss of business through referrals to the health facility.[126]

Schell et al. (2013) propose a framework of sustainability which incorporates these frameworks through conceptual mapping and expert input into nine broad domains: funding stability, political support, partnerships, organizational capacity, program adaptation, program evaluation, communications, public health impacts, and strategic planning **(Figure 3-1)**.[22] We use this framework to explore the sustainability of CEBS programs in Liberia.

Figure 3-1. Schell et al. (2013) Conceptual Framework on Sustainability[22]

3.2.3 Liberian Context

During the 2014-2016 West African EVD outbreak, 11,308 people died of the 28,610 reported EVD cases.[127] The surveillance system suffered from insufficient numbers of trained staff, community stigma, limited communication infrastructure, and an 'overwhelming number of affected persons".[10] Lessons from the outbreak highlighted the importance of community engagement and the characteristics of superspreading which drove transmission.[23,24] CEBS programs in Liberia were put in place during the tail-end outbreak, to respond to what a WHO Emergency Committee termed "the high mobility of populations and cross-border movement of infected travelers."[25–29] Reintroduction of the disease from ongoing transmissions chains in Sierra Leone occurred in 2016 from Guinea highlighted the need for increasing the sensitivity of the surveillance system in the porous border countries.[128]

In Liberia, the CEBS programs were managed jointly between international organizations and the Ministry of Health, supported by county and district health staff on the ground. Initially, there were a multitude of different forms, triggers, and reporting structures in used. As the epidemic waned in 2015, attention moved towards developing central MOH guidelines to standardize CEBS processes throughout the country, develop a long-term strategy, and identify opportunities to increase program coverage.[48] During this time, the CEBS was recognized as an integral component of both the community health policy as well as the IDSR strategy and integrated into the routine work of the MoH.[129,130] As operations were normalized and new resources established formally incorporated into the MoH, partners led by the MoH in a technical working group

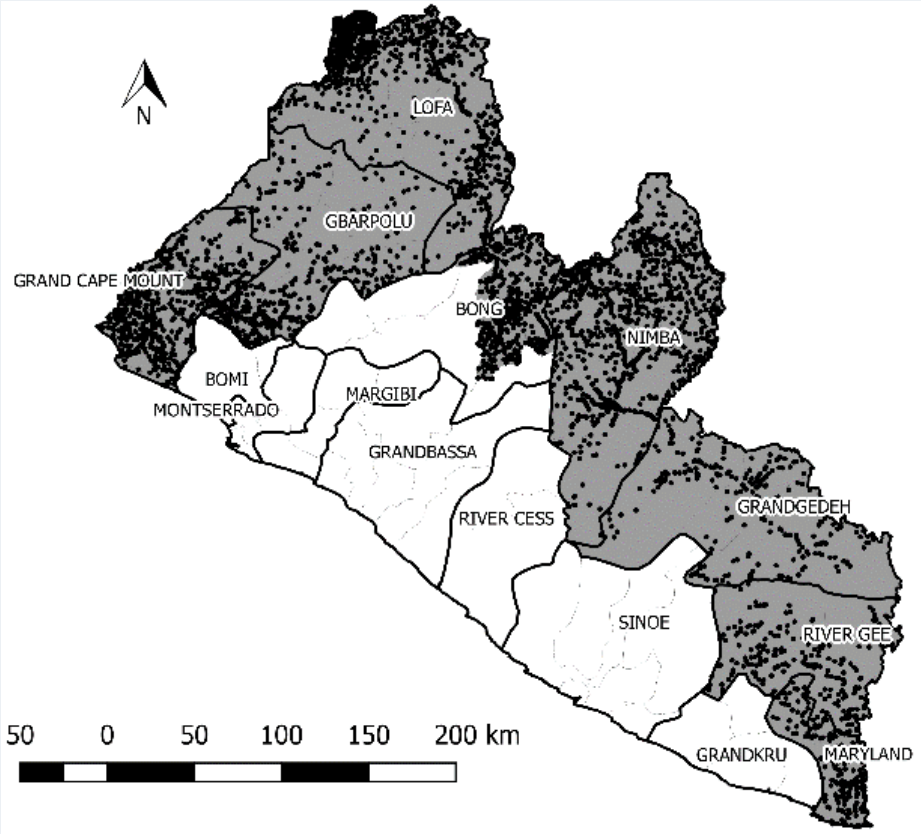
converged on a set of guidelines, forms, and process to standardize CEBS activities in the country.[131]

As part of the health system transition from emergency to routine functions, the CEBS program is adapting its format to achieve scale. This adaptation phase is an crucial step in identifying a sustainable path towards integrating CEBS as a permanent core function of all community surveillance workers in the country, and the lessons learned can inform similar referral programs in low-income settings.[116,119,132]

3.3 METHODS

There were multiple international organizations supporting and coordinating CEBS activities during the outbreak; we focus on the largest, supported by the International Organization for Migration. The program operated in the eight counties of Liberia with international land borders, Sierra Leone to the west, Guinea to the north, and Ivory Coast to the east (**Figure 3-2**). CEBS activities were nested in a more extensive border management project funded by USAID's Office of Foreign Disaster Assistance and implemented by the International Organization for MIgration. These counties were chosen to bolster the case detection near the porous land border, as the epidemic in Sierra Leone and Guinea continued. County officials mapped 2848 communities in 43 districts, covering an estimated 2,065,690 persons between April and September of 2016, accounting for approximately 36.5% of the population of the country.

Figure 3-2. CEBS Coverage



Community event-based surveillance programs were implemented in communities (black dots) in the eight border counties and covering only half of Bong County (dark shaded) from February to October 2016.

3.3.1 Program Operations

Trigger Definitions

Though the CEBS program in Liberia was a direct response to the ongoing Ebola epidemic, it was designed as an extension of the Integrated Disease Surveillance and Response program relaunched in 2016. In this manner, rather than a vertical program focused on Ebola, it was integrated into the surveillance system and focused on all priority diseases. A technical group devised community trigger definitions which

described prodromes or syndromes of the 14 priority diseases and conditions marked for immediate reporting by the Liberian IDSR Technical Guidelines[131]:

- *Acute Flaccid Paralysis:* Any person with weakness in the legs and arms or not able to walk
- *Measles:* Any person with hot skin and spot-spot and/or red eyes
- *Rabies:* Any person who is bitten by a dog or any other animal
- *Acute Bloody Diarrhea:* Any person passing bloody pu-pu or slimy (slippery pu-pu with stomach pain
- *Meningitis:* Any person with hot skin and stiff neck
- *Viral Hemorrhagic Fever:* Any person who has fever and two and two or more other symptoms (headaches, vomiting, runny stomach, weak in the body, yellow eyes), or who died after serious sickness with fever and bleeding
- *Acute Watery Diarrhea:* Running stomach. Any person passing three or more watery pu-pu within one day
- *Neonatal Tetanus:* Baby who is normal at birth, then after two days is not able to suck and starts jerking
- *Neonatal death:* Baby who dies at birth or within 28 days after birth
- *Maternal death:* Women who dies with big belly or within 42 days after baby is born or when the belly move
- *Unexplained cluster of disease:* Unknown health problems group together; any health problem that you don't know about that is happening to many many people or animals in the same community
- *Unexplained cluster of death:* Any death in human or group of animals that you don't know why it happened

CSWs and Program Staff

One community surveillance worker (CSW) was enrolled for every 100 households (approximately 350-500 persons), for a total of 2972 community surveillance workers in the program area. CSWs were nominated by Community Health Committees (CHC) with guidance from the catchment health facility and County Health Team. Selection criteria for CSWs included; (1) must be a permanent resident of the community, (2) between 18 and 50 years of age, trustworthy and interested, (3) be able to read, write, add, subtract, and multiply and complete an English literacy test.[133] All enrolled CSWs were provided a

nominal $30 incentive and provided rain gear and essential supplies to aid in travel during the rainy season.

CSWs were supervised by health facility clinicians, either the officer-in-charge or designate. In early 2016, a series of week-long trainings were held for CSWs, clinicians, and district/county surveillance officers on the trigger definitions, reporting structure, supervision, and response. CSWs were trained to identify and communicate with key informants and rumor sources (businesses, markets, schools, pharmacies, traditional healers) within the community to detect suspect alerts.

Reporting

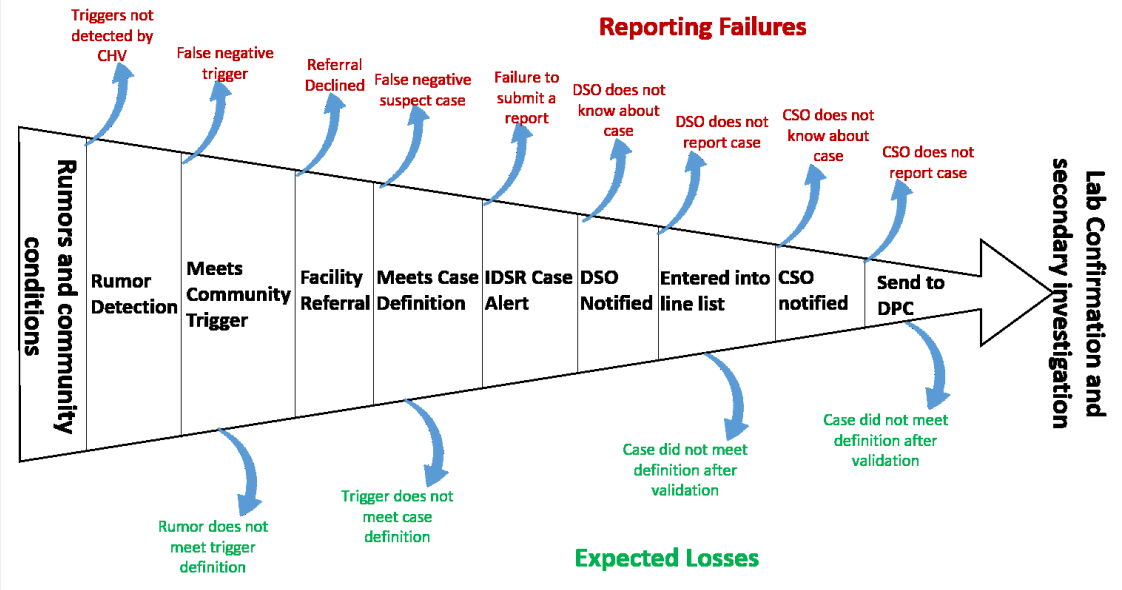
Upon detecting a rumor or making a household visit, the CSWs directly observed the patient and matched against the community trigger definition. If the definition was met, the CSW filled out the CEBS Alert Form and gave it to the patient to take with them to the health facility.

After the patient arrives at the health facility, the clinician verifies the patient matches a community case definition, and further evaluates the case against the corresponding IDSR case definition. If the patient returns to the community for outpatient services, the clinician fills the bottom half of the referral form with follow-up instructions for the CSW.

If the patient does match an IDSR case definition, they become a suspect case, and the health facility fills out the IDSR Case Alert Form. The case is managed through the real-time disease surveillance reporting chain, making its way to the laboratories and

the national level. The desired notification time for an IDSR priority case is 24-48 hours (**Figure 3-3**).

Figure 3-3. Simplified Reporting Flow and Common Losses in CEBS



Supervision and Coordination

Supervision and coordination structures were instituted at each subnational level. CSWs are directly supervised by a clinician at the health facility. The Community Health Services Supervisor (CHSS), a permanent cadre developed to focus on community outreach and supervision of community surveillance workers is currently being recruited. Temporarily, twelve local NGOs were recruited to supplement health facilities resources and provide weekly mentorship of CSWs. Field officers validated alerts against the community case definition and verified data quality of the information.

Health facilities are supervised by the District Surveillance Officer (DSO), a surveillance professional trained in Frontline Epidemiology Training Program (FETP). DSOs are responsible for reporting to the counties, coordinating with the district health

team (DHT), and investigating and escalating suspect cases of the epidemic-prone disease.

The CSW is an active member of the Community Health Committee and gives routine updates or 'health talks' at large. CSWs also gather routinely at the health facility as part of the Health Facility Development Committee. A CEBS implementation team was formed in each county, where county, district, health facility, and community representatives meet monthly to guide the implementation and adapt to the ongoing development of the surveillance system post-Ebola. At the national level, a community event-based surveillance technical working group was formed to standardize reporting structures and coordinate aid between partners operating CEBS programs in other areas of the country.

3.3.2 Evaluation

The evaluation of the CEBS program consisted of a desk review of program documents, in-depth interviews with program managers, observations from direct participation in technical working groups, an interviewer-administered survey.

Desk Review

A Brief Glossary of Diagnostic Terminology applied to CEBS

- Trigger – the community trigger definition describes a constellation of signs and symptoms which are syndromes or prodromes for a disease or event of public health concern
- Alert – a report of a patient who exhibits a trigger to the surveillance system
- True Alert – an alert which met the trigger definition (verified weekly by HF supervisors)
- False Alert – an alert which did not meet the trigger definition (verified weekly by HF supervisors)
- Case – a patient who fits the suspect, probable, or confirmed case definition
- True Positive – an alert which became a case (compared against IDSR records)
- False Positive – an alert which did not match a case definition (compared against IDSR records)
- False Negative – a case in the population which was never alerted (not directly measured in this study)

The primary objective of syndromic surveillance is to improve the sensitivity of case detection and provide early warning for a public health response. High sensitivity decreases the number of 'missed cases' (false negatives) in the population. There is no clear benchmark for sensitivity, as it is dependent on local context, disease, and objectives of the surveillance system. In Liberia, where the focus of CEBS was on infectious disease and high impact conditions, the aim was to capture cases which would not otherwise be reported by the health facility.

High sensitivity targets are not always necessary, surveillance systems with low but consistent sensitivity can be informative when assessing disease trends and risk.[134] Sensitivity targets can also change depending context - during outbreaks case definitions can be flexible if a higher sensitivity is necessary. Comparison of program performance based on sensitivity between programs is problematic as the measure depends heavily on the trigger definition.[135]

Measuring sensitivity requires a gold standard comparison which captures all cases in the target population. It is difficult to identify a gold standard for syndromic surveillance systems. The most common gold standard is a household survey; however, these surveys estimate the prevalence based on probability sampling and may not identify missed outbreaks at the subnational level. Routine household surveys focus on a small subset of disease conditions, and seldom encompass rare diseases. Two pass verifications are also common, wherein experienced supervisors identify cases in the community and compare against cases identified by CSWs.

For this analysis, we are unable to directly calculate sensitivity as we lack an external gold standard. Instead, we measure *coverage*, or the proportion of cases in the National Disease Surveillance Information System (DSIS) database which originated in CEBS. The DSIS is the warehouse containing case-based reports of all immediately reportable disease in the country. DSIS derives its data from passive reporting from health facilities, active outbreak investigations, and immunizations campaigns. We expect a well-functioning CEBS program would report the bulk of its cases at the community level for the selected triggers. However, without an independent reference, we are unable to quantify false negatives which were not detected by either CEBS or the routine surveillance system. As during the EVD outbreak underreporting was estimated as a high as 60% in some areas, this is a considerable limitation.[66] Using DSIS as a standard, false negatives are representative of:

- Cases missed at the community but detected by the health facility (e.g., the case did not exhibit the trigger, CSW was not aware of the case, or patient self-refers)
- Cases detected in the community, but not reported or validated (e.g., patient refusal or inability to reach the health facility or facility/district officers were not able to see the patient)
- Cases with symptom onset at the health facility (e.g., maternal death, neonatal death, etc.)
- Cases detected through outbreak investigation (e.g., the first measles case may have been detected through CEBS, but subsequent cases were picked up through active investigation; or AFP detected through immunization campaigns)

In our desk review, we use the following metrics:

Coverage defined as the proportion of all cases in the disease surveillance system captured through CEBS. Calculation of coverage is hampered by reporting loses between the health facility and national level.[28] The database contains a field to indicate whether a case the health facility was reporting was a result of a CSW. However, it was not reliably collected. As a result, we cannot verify if all confirmed alerts are reflected in the national database. In the established reporting process, all alerts which meet the case definition would be reported to the national level within one week. To compensate, we define a high and low estimate, where the true value will likely fall between as:

$$Pr(+|D)_{low} = \frac{\#alerts\ meeting\ case\ definition}{\#\ total\ cases\ in\ National\ Database + \#alerts\ meeting\ case\ definition}$$

$$Pr(+|D)_{high} = \frac{\#alerts\ meeting\ case\ definition}{\#\ total\ cases\ in\ National\ Database}$$

Positive predictive value (PPV) defined as the proportion of all alerts which met the trigger definition which also met the IDSR case definition. PPV was calculated by dividing the number of cases by the reported cases detected through CEBS.

$$Pr(D|+) = \frac{\#\ alerts\ meeting\ case\ definition}{\#\ alerts\ meeting\ trigger\ definition}$$

Rate of reported triggers represents a population standardized metric of the diagnostic sensitivity of CEBS activities. This is not a perfect comparison as the disease burden may be higher or lower dependent of geographic area. This will also be heavily impacted by outbreaks, which may vastly increase the number of reported triggers compared to the standard background detection rate.

Sustainability

Sustainability was reviewed using the Schell sustainability framework. In-depth interviews were conducted with the National Community Event-Based Surveillance Technical Lead, Community Health manager, IOM implementation manager, and Director of Department of Infectious Disease Epidemiology. The review also used minutes from the CEBS evaluation review discussion and observations based on personal attendance in the CEBS Technical Working Group.

Interviewers

Interviewers were provided from the International Organization for Migration program staff and WHO national staff. The staff was supervised by external consultants and a MOH observer. Interviewers were trained in best practices, surveys, and electronic reporting into tablets using OpenDataKit. When tablets were inoperable, the teams reverted to paper forms, and double entered the data into ODK at a later date. Though there is an English standard for all cadres, interviewers were trained to simplify translate and questions into the local dialect.

The instrument was adapted from the newest iteration of the Performance of Routine Information System Measurement (PRISM) used to assess routine health information systems within health facilities. The survey assessed knowledge of triggers, infrastructure, reporting, supervision, and behaviors.

Respondents & Sampling Methods

All CSOs and DSOs were administered the survey by phone. For health facilities and community workers,, the survey used a multi-level, multi-stage cluster sampling approach:

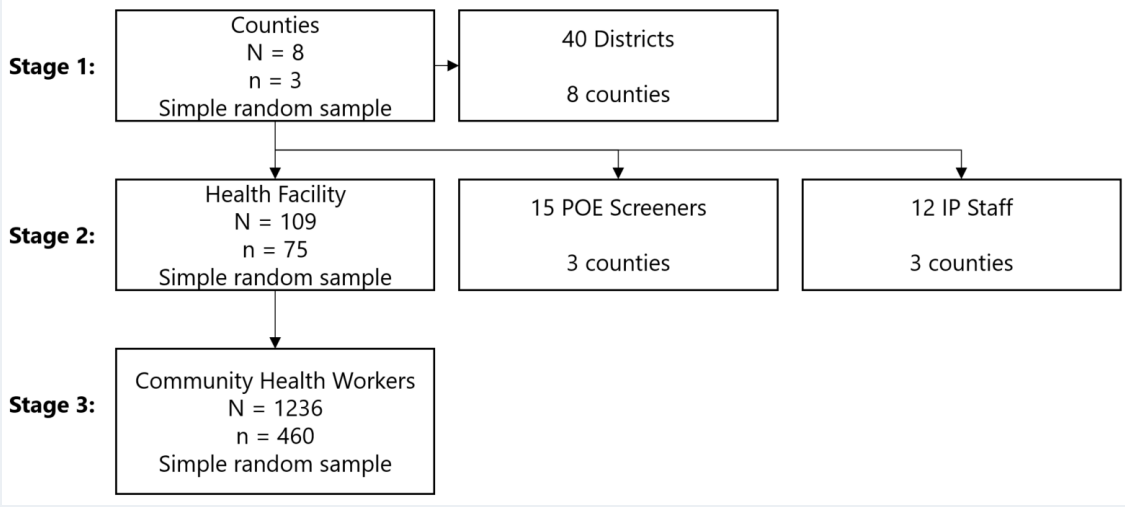
Stage 1. Random selection of counties implementing the program

Stage 2. Random selection of health facilities

Stage 3. Random selection of community surveillance workers

In Stage 1, the county surveillance officer, district surveillance officers, implementing partner field surveillance staff, and point-of-entry screeners were selected for surveys. In stage 2, the surveillance focal person (SFP) of health facilities in the selected counties were surveyed, usually the officer-in-charge of the facility. In stage 3, community surveillance workers were selected in the catchment areas of the selected health facilities. The number of health facilities and community surveillance workers sampled was based the available time and number of interviewers available during the two-day program close-out session. As a result, the sample is not self-weighted. A weight of $w_{ij} = \frac{1}{\frac{n}{N}*\frac{k_i}{K_i}*\frac{m_{ij}}{M_{ij}}}$ is applied where $n = sampled\ counties$, $N = total\ counties$. For the i^{th} sampled county, k_i health facilities sampled of the total K_i health facilities. For the j^{th} sampled health facility, m_{ij} community surveillance workers of the total M_{ij} community surveillance workers. Due to the relatively large proportion of the program population was sampled, a finite population correction was applied.

Figure 3-4. Multilevel multistage sampling scheme



3.4 RESULTS

Between Epidemiological Week 15 and 38 (April to September) 2016, the program generated an average of 156 alerts and 37 suspect cases per week in the eight counties. Overall, 3,746 alerts were reported. The rates were driven by acute watery diarrhea, accounting for 45.9% of all reports, followed by Viral Hemorrhagic fever (15.5%), and measles (11.1%) (Table 3-1).

Table 3-1. CEBS Program Results

Alerts	Reported #	Met Trigger Definition #	Met Trigger Definition %	Met Case Definition #	Met Case Definition %	Positive Predictive Value	Cases in National Database	Coverage high-low est
Acute Bloody Diarrhea	262	230	88%	37	14%	16.1%	75	49-33%
Acute Watery Diarrhea	1720	1,575	92%	485	28%	30.8%	19	100-96%
Cluster of Unknown Diseas	78	64	82%	39	50%	60.9%	0	100%
Maternal Death	36	33	92%	27	75%	81.8%	82	33-25%
Measles	417	370	89%	61	15%	16.5%	162	38-27%
Meningitis	143	125	87%	13	9%	10.4%	19	68-41%
Neonatal Death	76	71	93%	50	66%	70.4%	131	38-28%
Neonatal Tetanus	30	28	93%	9	30%	32.1%	3	100-75%
Acute Flaccid Paralysis	80	71	89%	10	13%	14.1%	12	83-46%
Animal Bite	190	180	95%	64	34%	35.6%	114	56-36%
Unexplained Death	135	117	87%	50	37%	42.7%	0	100%
Viral Hemorrhagic Fever	579	505	87%	40	7%	7.9%	6603	0.6%
Total	3746	3369		885			7220	

The majority (95%) of reported alerts met the community trigger definition. Of these, 885 met the suspected, probable, or confirmed IDSR case definition and were reported to the district level for further investigation. The positive predictive value was highest for reports of death: maternal death (81.8%), neonatal death (70.4%), and unexplained death (42.7%). The system also had high PPV in the detection of clusters of unknown disease (60.9%). Conversely, there was low PPV for rare diseases of epidemic potential; VHF (7.9%), meningitis (10.4%) and acute flaccid paralysis (14.1%).

Cases identified through CEBS were not often recorded in IDSR, as evidenced by the lack of cases for clusters of unknown death and unexplained disease. Based on this, the lower estimate of coverage which assumes none of the cases in CEBS are included in the IDSR database is likely more accurate. Coverage was highest for the clusters of unknown death and disease, neonatal tetanus, and acute watery diarrhea (100%). Coverage was above 25% for all diseases except viral hemorrhagic fever at 0.6%. Disregarding the EVD reporting (which was highly sensitive and had multiple active surveillance initiatives ongoing) and using IDSR numbers as an upper limit, we estimate

that 31.% of IDSR cases in these 8 counties originated in CEBS reporting., using the low estimate

Table 3-2. Annualized Trigger Report Rate per 100,000 (Annualized Suspect Case Identification Rate per 100,000) by County

Disease Trigger	Bong	Gbarpolu	Grand Cape Mount	Grand Gedeh	Lofa	Maryland	Nimba	Rivergee	Grand Total
Acute Bloody Diarrhea	61.8 (4.3)	6.5 (2.2)	2.9 (2.9)	128.4 (5.5)	13 (0.7)	31.8 (3.8)	13.8 (5.3)	116.3 (27)	34.5 (4.9)
Acute Flaccid Paralysis	10.1 (0)	2.2 (0)	0 (0)	0 (0)	13 (5.8)	14 (1.3)	4.9 (0.4)	83.8 (0)	10.5 (1.3)
Acute Watery Diarrhea	701.5 (215.6)	36.7 (17.3)	54.5 (24.4)	464.6 (51.9)	214.1 (75.2)	192.3 (34.4)	69.2 (35.2)	592.2 (146)	226.4 (63.8)
Maternal Death	4.3 (4.3)	6.5 (6.5)	5.7 (1.4)	4.1 (1.4)	5.1 (4.3)	2.5 (1.3)	4.9 (4)	5.4 (5.4)	4.7 (3.6)
Measles	178.2 (0)	0 (0)	0 (0)	86.1 (0)	50.6 (26.8)	48.4 (11.5)	11.3 (2.4)	254.2 (24.3)	54.9 (8)
Meningitis	60.4 (0)	15.1 (0)	1.4 (0)	28.7 (1.4)	1.4 (1.4)	15.3 (5.1)	6.9 (0.8)	110.9 (10.8)	18.8 (1.7)
Neonatal Death	11.5 (7.2)	12.9 (8.6)	5.7 (4.3)	10.9 (1.4)	3.6 (2.2)	6.4 (1.3)	8.1 (5.7)	54.1 (51.4)	10 (6.6)
Neonatal Tetanus	4.3 (1.4)	2.2 (2.2)	0 (0)	1.4 (0)	5.1 (2.9)	5.1 (0)	2.4 (1.2)	21.6 (0)	3.9 (1.2)
Human Rabies	33.1 (14.4)	2.2 (0)	7.2 (1.4)	39.6 (10.9)	10.9 (2.9)	17.8 (1.3)	36.4 (15)	35.2 (8.1)	25 (8.4)
Unexplained Death	20.1 (8.6)	10.8 (2.2)	8.6 (2.9)	20.5 (6.8)	8 (0.7)	17.8 (7.6)	11.7 (8.9)	110.9 (18.9)	17.8 (6.6)
Unexplained Diseases	24.4 (18.7)	0 (0)	0 (0)	5.5 (5.5)	0 (0)	21.7 (1.3)	5.3 (2)	73 (43.3)	10.3 (5.1)
Viral Hemorrhagic Fever	58.9 (0)	10.8 (0)	1.4 (1.4)	233.7 (2.7)	65.1 (8)	57.3 (6.4)	31.5 (4.9)	400.2 (24.3)	76.2 (5.3)
Grand Total	1168.6 (274.5)	105.7 (38.8)	87.4 (38.7)	1023.5 (87.5)	389.9 (130.9)	430.5 (75.1)	206.3 (85.7)	1857.8 (359.7)	493 (116.5)

Annualized reported rates (Table 3-2) differed massively between counties, highest in Bong (1166.6 reports per 100,000) driven by reporting of acute watery diarrhea, and lowest in Gbarpolu, the most rural and lowest population of Liberia's counties. Overall, there were 493 reports per 100,000 persons.

A total of 1246 CSWs were recruited to serve the eight counties. Approximately 80.6% of the CSWs were male, with an average age of 37 years. The majority (68.5%) of CSWs had completed high school. Nearly 70% of CSWs had another source of income, and 41.1% provided other health services through government programs. CSWs reported they spent an average of 3.6 hours per day on health activities. On average, 72.2% of CSWs walked to the health facility, and 64.3% of CSWs walked more than an hour away (Table 3-3). Each CSW reported an average of 3 alerts during the program period.

Table 3-3. Community surveillance worker Characteristics (n=465)

	Mean/%	Std. Err.	[95% Conf. Interval]	
% Male	80.6%	0.030	64.7%	90.4%
CHV Age in Years	37.0	1.367	31.2	42.9
Percentage of CHVs who completed:				
Elementary	7.1%	0.025	1.5%	28.0%
Junior High	24.5%	0.027	14.9%	37.7%
Senior High	64.7%	0.050	41.7%	82.4%
College/University	3.2%	0.008	1.0%	9.3%
Other	0.6%	0.003	0.1%	5.3%
Percentage of CHVs who travel to HF by:				
Walking	72.2%	0.054	44.9%	89.2%
Motorbike	25.4%	0.046	10.8%	49.1%
Car/Taxi	2.2%	0.012	0.2%	18.8%
Other	0.2%	0.002	0.0%	11.7%
CHVs with another source of income	69.7%	0.026	58.6%	80.9%
CHVs which provide other health services	41.1%	0.045	21.8%	60.3%
Average # hours spent per day on health activities	3.6	0.3	2.5	4.7
Percentage of CHVs who travel for more than one hour to reach the health facility	64.3%	0.070	34.1%	94.5%

CSWs were asked for an on-the-spot recall of trigger definitions. Recall percentages were highest for acute watery diarrhea (83.7) and lowest for clusters of unknown disease (19.3) and unexplained death (20.7%) (Table 3-4). These patterns were similar at all levels, with national priorities (maternal death, viral hemorrhagic fever) increasing in recall percentage among CSOs and national staff.

Table 3-4. Trigger Recall (n=465)

	%	Std. Err.	[95% Conf.	Interval]
Proportion of CHVs who recalled trigger for:				
Acute Flaccid Paralysis	61.9%	0.023	52.1%	71.8%
Acute Watery Diarrhea	83.7%	0.022	74.4%	93.0%
Acute Bloody Diarrhea	69.6%	0.041	52.1%	87.0%
Human Rabies	59.8%	0.037	44.0%	75.6%
Measles	63.8%	0.055	40.1%	87.5%
Viral Hemorrhagic Fever	60.8%	0.048	40.3%	81.3%
Meningitis	47.8%	0.055	24.2%	71.5%
Maternal Death	63.5%	0.018	55.8%	71.2%
Neonatal Tetanus	44.7%	0.028	32.8%	56.5%
Neonatal Death	47.9%	0.015	41.6%	54.2%
Cluster of Unknown Disease	19.3%	0.024	8.9%	29.7%
Cluster of Death	20.7%	0.047	0.6%	40.9%

The most popular source of information and rumor gathering from the CSWs was from house to house visits and general word-of-mouth (75.2%) (Table 3-5). Religious and community organizations, community leaders, and businesses/markets accounted were utilized by 40% of CSWs. About 1 in 5 CSWs linked with other health providers such as midwives (22%) or traditional healers (23.3%). About 10.4% of CSWs elicited information from medicine stores and pharmacies.

Table 3-5. Information finding in the community (n=465)

	%	Std. Err.	[95% Conf. Interval]	
Community members get health information from:				
Other people in the community	66.2%	0.02	55.8%	76.6%
Radio	57.3%	0.06	29.7%	85.0%
Other people in the community	32.4%	0.02	22.0%	42.8%
People working with the health system	31.0%	0.06	5.8%	56.2%
Newspaper	4.2%	0.02	0.0%	12.3%
Television	0.6%	0.00	0.0%	2.6%
CHVs get information from:				
Other people in the community	72.5%	0.02	62.3%	82.8%
Churches, mosques, or community orgs	45.3%	0.08	11.0%	79.6%
Community leaders	40.5%	0.03	26.8%	54.2%
Stores, businesss, and markets	40.2%	0.06	13.7%	66.7%
Local school	23.5%	0.02	13.0%	34.1%
Traditional leader	23.3%	0.02	15.1%	31.4%
Other healers or midwives	22.0%	0.04	5.5%	38.5%
Other sources of information	12.8%	0.02	3.0%	22.6%
Pharmacy or medicine store	10.4%	0.03	0.0%	23.3%

A significant challenge reported by CSWs was the refusal of community members to go to the health facility after a referral (Table 3-6).

Table 3-6. Barriers to Care-Seeking as reported by CSWs (n=465)

	%	Std. Err.	[95% Conf. Interval]	
What is the main reason patients refuse referral to the health facility:				
Too far, no transportation	34.2%	0.05	0.18	0.56
Transportation too expensive	22.9%	0.03	0.12	0.40
Inconvenient hours	20.1%	0.04	0.08	0.42
Thought it would go away by itself	14.4%	0.03	0.06	0.30
Other reason	12.0%	0.01	0.08	0.17
Services too expensive	7.7%	0.01	0.03	0.17
No one to accompany me	7.7%	0.01	0.05	0.13
Religious Beliefs	4.9%	0.01	0.02	0.14
Unfriendly staff	4.8%	0.01	0.02	0.10

The top two reasons for refusal were transportation related, 34.2% reported the health facility was too far, and no transportation was available, and 22.9% said the available transportation was too expensive. Issues with the health facility were also prevalent, 20.1% said the facility kept inconvenient hours (most open from 9-5pm), 7.7% reported the services (mostly prescriptions) were too expensive, and 12% reported the drugs were usually unavailable.

Table 3-7. Challenges reported by field staff (n=595)

	% of cadre reporting challenge				Total
	CHV (n=465)	OIC (n=81)	DSO (n=41)	CSO (n=8)	
Transportation	56.2%	47.0%	69.2%	25.0%	55.3%
Need more incentive	25.5%	16.9%	15.4%	37.5%	23.8%
Communication is difficult	10.0%	41.0%	59.0%	62.5%	18.2%
Not enough supplies*	14.5%	12.0%	15.4%	62.5%	14.8%
No respect/attention from community	17.2%	2.4%	2.6%	0.0%	14.0%
Refusal of community to use service or go to the health facility	15.7%	6.0%	2.6%	0.0%	13.3%
Not enough CHVs or too big area of coverage	4.7%	9.6%	2.6%	0.0%	5.2%
More training needing	0.4%	6.0%	10.3%	0.0%	1.8%

*Supplies include rain boots, backpacks, ledgers, forms, jobs aids, etc
**Refusal because of lack of trust in health facility to deliver care, preference for traditional healers, etc

Most (94.5%) of CSWs discussed community health issues with the health facility weekly (Table 3-8). About 72.7% received feedback from the health facility after referring a patient to the health facility. While 88.8% of OICs reported the DSO visited the health facility weekly, only 62.5% reported the DSO specifically asked about CEBS reporting and reviewed community data. This was mirrored between the district and county level,

where 64.1% of DSOs reported discussing community data with the CSO. About 82.1% of DSOs reported being a part of the CEBS implementation team.

Table 3-8. Supervision

	Proportion of [cadre] who has weekly:	n	%	Std. Err.	[95% Conf	Interval]
CHV Respondents (n=465)	Feedback from the health facility supervisor on community referrals	465	72.7%	0.03	59.2%	86.3%
	Discussions with health facility about community health issues	465	94.6%	0.02	87.5%	101.7%
Health Facility Respondents (n=81)	CHV discussions on the outcome of a referral and next steps?	81	71.6%	5.0%	60.6%	80.5%
	Does the DSO weekly….					
	ask about cases of priority disease that you saw	81	88.8%	0.04	81.7%	95.8%
	talk to you about the data completeness, quality, and timeliness of IDSR reporting	81	63.8%	0.05	53.0%	74.5%
	look at your HMIS logbooks to see if there are any other cases of interest	81	33.8%	0.05	23.2%	44.3%
	look at the CEBS reporting forms	81	62.5%	0.05	51.7%	73.3%
District Surveillance Officers (n=41)	Visits to health facilities to identify IDSR cases	41	87.2%	0.05	76.2%	98.2%
	Feedback to OICs about CEBS and POE triggers	41	71.8%	0.07	57.0%	86.6%
	Meetings with the DHO to discuss IDSR performance and reporting of health facilities	41	61.5%	0.08	45.6%	77.5%
	Meetings with the entire DHT to review IDSR cases	41	25.6%	0.07	11.3%	40.0%
	Meetings with the CSO to review IDSR data	41	66.7%	0.08	51.2%	82.1%
	Meetings with the CSO to review CEBS and POE data?	41	64.1%	0.08	48.3%	79.9%
	Meetings with the CSO talk to you about the data completeness, quality, and timeliness of your IDSR reporting?	41	84.6%	0.06	72.8%	96.5%
	Meetings with the community health committee?	41	74.4%	0.07	60.0%	88.7%
	Are you a part of the CEBS implementation team?	41	82.1%	0.06	69.4%	94.7%

3.4.1 Sustainability

An analysis of sustainability is summarized in Table 3-9. Emergency response to the Ebola epidemic left strong community structures and a general appreciation for the importance of health surveillance. Liberia also benefited from the lack of path dependency, with a previous CSW program collapse in 2007. The revised Community Health Policy was under development concomitantly and integrated CEBS activities into its core package. The policy supports a cadre of Community Health Assistants (CHA) who

perform a package of health services, and are incentivized at $70 per month. The community health program has secured long-term funding but is limited in scope to remote areas outside 5 kilometers from the nearest health facility, covering about 70% of the population.[133] The remainder of the country will be a partnership with a patchwork of NGOs, but funding is sporadic, and only part target population is currently covered.

Table 3-9. Sustainability Framework[22] applied to Liberia CEBS Program

Political Support	internal and external political environment which influence program funding, initiatives, and acceptance	• Leadership supports the program, but grapple with competing priorities and diminishing resources post-outbreak • Operational responsibility is split between the Community Health Program in the Ministry of Health, and the Department of Infectious Disease Epidemiology in the National Public Health Institute. As the NPHIL is a new institution, there is not yet any clear coordination bodies to manage joint programs • CEBS is broadly recognized at all levels of the health system as a core activity part of the broader IDSR strategy for early warning of disease
Funding Stability	making long-term plans based on a stable funding environment	• The initial funding was tied to outbreak-related emergency funding, the mechanisms for continued support must be found elsewhere • CEBS activities outside of a 5km radius of a health facility have been integrated into long-term funding for the community health program • Funding for the remainder (70% of the population) is currently piecemeal through NGO partners working in different areas of the country • Options exist for alternative incentive schemes and further integration of program activities
Partnership	the connection between program and community	• There is a defined structure for engaging communities in referrals through the community health committee • The CEBS implementation team incorporates community representatives for input into program operations • The stigma of reporting health conditions remains high • Other health providers in the community need to be engaged
Organizational Capacity	the resources needed to manage the program effectively	• Since program inception, surveillance staff have been hired and trained in CEBS activities • High turnover of staff requires frequent refresher training • A limited number of health facility staff, especially clinicians targeted at fieldwork, create a burden on supervision and assessments of patients who cannot travel to the facility • Lack of resources for transportation and communication continues to be a pervasive barrier to referral and reporting of cases
Program Evaluation	monitoring and evaluation of process and outcome data	• The program has defined indicators integrated into routine supervision, mentorship, and monitoring tools, as well as external assessments such as JEE • Absorption and translation of the data are difficult beyond the basic assessment of the proportion of cases detected in the community. More advanced analysis such as hot-spots and signal analysis used for syndromic data is not in use
Program Adaptations	the ability to adapt and improve	• Technical bodies and multi-stakeholder representation (community health committee, CEBS implementation meetings, CEBS technical working group) provide platforms for continuous review and adaptation of program activities • Clear lines of reporting and supervision provide a pathway for quick dissemination of programmatic changes such as new triggers, allowing the program to be responsive to epidemics

Communications	the dissemination of program outcomes with stakeholders	• All messages and forms are tested by the health promotion professionals at the Ministry of Health • Job aids were devised to help the community better understand the signs and symptoms of the triggers, and understand the potential risk of epidemic-prone disease • Defined health promotion strategy • Ongoing feedback to the community through routine 'health talks'
Health Impacts	the program's effect on the health of the area	• It is difficult to quantify the impact to health after the identification of suspect cases • CEBS mechanisms were used for health promotion activities in cases of Rift Valley Fever, measles, and animal bites
Strategic Planning	the process that defines program direction, goals, and strategies	• Program activities are built into the 5-year Community Health and Disease Surveillance strategies • Technical bodies meet routinely to discuss program activities and direction, and is included a yearly program review of disease surveillance programs
Data from in-depth interviews, community surveillance worker surveys, financial and operational documents, and participation in technical group meetings		

The introduction of the CEBS program in Liberia was funded by international donors through emergency funding. The program covered an estimated 1.8 million persons in the eight counties, many of them in some of the hardest to reach areas of the country. The annualized expenditure per capita was 3.69 USD. CSWs only provided CEBS activities, and this cost is not shared with other programs, though integration into the larger community program is planned. About 44.5% (1.64 USD) of this cost was associated with salaries for local and international NGO staff. About 25.6% (0.95 USD) of this cost was related to overhead, field offices, etc. The remaining 29.9% (1.10 USD) of the cost was related to workshops and incentives.

The other bottleneck to sustainability is the disjointed political ownership of the program. Technical inputs for CEBS activities are typically shared between Community Health, Health Information Systems, and Disease Surveillance units. In most settings, Community Health units will be responsible for implementation, with technical input from other units. In Liberia, these national working groups exist, but competing priorities often take precedence, and much of the coordination relies on information relationships.

3.5 DISCUSSION

The impact of CEBS on the overall coverage and timeliness case detection is difficult to quantify as the disease surveillance information system was developed alongside the implementation of the program. However, the ability of CEBS to capture and detect cases is without question. Between April and September of 2016, the program reported 3746 alerts and 885 suspect cases of the disease. CEBS detected approximately one in eight suspected cases of immediately reportable conditions.

Disease Triggers

Selection of community case definitions is guided by disease control goals. In this study, we found CSWs were able to recall on average six of the ten case definitions. Prevalent diseases (e.g., watery diarrhea, measles) and high impact conditions (e.g., maternal death, neonatal death) were most likely to be remembered. The PPV was also low for conditions with a broad community trigger definition, such as acute watery diarrhea, despite its high prevalence.

By far, the lowest recall rates were for the less specific triggers for unknown clusters of death or disease. These triggers, which emphasize general vigilance for 'Disease X,' are arguably the most critical function of community surveillance. This result implies that mixing prevalent/specific triggers with rare/amorphous triggers can result in a de-emphasis of the amorphous triggers. For programs which aim to focus on abnormal events, the solution is not necessarily to remove prevalent conditions from the program. Communities value CSWs who are responsive to immediate health needs and are more likely to utilize them.[136,137] Inclusion of these prevalent triggers also provides an

opportunity to practice activities and receive feedback from the health facility. Instead, the programs should emphasize the identification of abnormal events at every opportunity. Training should utilize simulations focusing on abnormal events, and supervisors should be instructed routinely inquire if anything else abnormal happening within the community.

Regardless, over 95% of reported alerts matched the community case definition, indicating CSWs were able to efficiently screen patients in the community and did not overload facilities with false negatives. PPV was lower than expected for some conditions. Viral hemorrhagic fever (PPV = 0.6%) had high numbers of reports due to the heightened case detection following the EVD outbreak. Measurement of PPV is affected by prevalence, and thus less prevalent conditions will naturally have lower PPV rates.

Trigger selection for CEBS can be determined by identifying the conditions which require a higher sensitivity than is being achieved by the facility-based surveillance system and (1) have easily identifiable prodromes or syndromes (3) can reduce overall morbidity or mortality through early detection (4) will not overload the CSWs or health facilities or (4) provide valuable syndromic information for risk mapping.

Community Case Finding and Referral

All cases of an unknown disease and unexplained death in the national surveillance system originated from community-based reporting. This result highlights the most significant advantage for CEBS activities – early identification of emerging public health threats. Reporting unknown events allows communities to self-report health concerns, rather than relying on health facilities in remote areas to identify these

trends. It also captures events such as sick livestock and unexplained deaths which otherwise may not be reported to the health facility.

Word-of-mouth was by far the most common mode of case detection. CSWs were insufficiently connected to other key sources of information, particularly other health providers such as traditional healers, herbalists, and midwives. These community health providers often have a competitive outlook towards community referrals as they lose business. Going forward, including these health providers in CEBS training or incentivizing referral from these cadres may increase linkage to care rates.

The vast majority of CSWs reported the community trusted the CSW and talked about their health conditions, despite 80% of CSWs reporting sick persons often face stigma. The CSWs were also able to navigate referral refusals by reasoning with the patient and notify the town chief. As expected, the most significant barrier to care seeking was transportation. Many CSWs worked with communities to mobilize transportation resources such as hammocks and motorbikes. These sort of contingencies for patient transport should be formalized, such as connecting CSWs to ambulance services or providing field surveillance officers with transportation equipment and logistics support.

Interactions with the Facility-Based Surveillance System

Multiple disease conditions with a lower number of suspect cases in the national database compared to programmatic data indicate a significant reporting loss between the community and the national level. This is a common difficulty, where turnover of already limited health professionals and heavy reporting responsibilities unravel the

connection between CEBS and facility-based reporting.[93,138] Routine discussion of CEBS data at surveillance meetings and inclusion of subnational surveillance staff in operational meetings will act as reinforcing influences on this connection. It is essential to view the connection between CEBS and the surveillance system as a two-way street rather than a unidirectional reporting pathway. The surveillance system can leverage CSWs to improve risk communication, quickly respond to newly emerging threats, and gain access to community structures.

Building information systems and staff to handle the influx of community surveillance data should is a significant investment often neglected when implementing CEBS programs. Community data systems produce an enormous amount of data which are difficult to absorb and translate into action in real-time at the national level.[93,138] At the facility level, information use is often organic and informal. In Liberia, one clinician reported how a diarrhea case helped identify a community with a broken hand pump and poor sanitation conditions using contaminated water from a nearby creek. Some clinicians leveraged CSWs during measles outbreaks to identify cases and provide additional health promotion.

Sustainability

The CEBS program, if sustained without change for a year would account for 0.3% of GDP per capita in 2016 (PPP) and 19.4% of the domestic government health expenditure per capita (PPP).[16] This high cost is a consequence of maintaining parallel surveillance and reporting structures during the restructuring of the national surveillance system. Going forward, there are opportunities for cost sharing with the planned national

community health program. We estimate a government-run vertical program will cost 2.04 USD per year; 43% of the cost is the incentive ($30/month) and 41% for supervision, training, and coordination meetings. If CEBS activities are fully integrated into a nationwide community health program (as planned), the additional cost for CEBS activities is estimated to be 0.55 USD per capita, assuming shared costs for joint training, supervision, and for surveillance staff but not incentives. This is similar to costs reported by other integrated CEBS programs, and would reduce the cost share to 2.9% of the domestic government expenditure on health per capita.[102,139] We argue that as a common good for health and resiliency to health shocks, this is affordable compared to the cost of clinical care. Integration into the broader community services program would also distribute the management burden. Currently, the program is managed at the national level by the disease surveillance unit, and at district and county levels by surveillance officers. Integration would shift the data analysis tasks to monitoring & evaluation officers, and day to day management to the community services staff, freeing the epidemiologists to focus on use of information and verification of alerts.

A significant portion of the cost of CEBS is in the incentive. The appropriate amount and type of incentive will depend on the scope of activities a CSW must perform. For CEBS programs which are passive or less formal, relying on pure altruistic motives and pure volunteerism is a viable option. When asked what alternative incentives would be acceptable, 11% of the CSWs reported no incentive was needed, or only simple identification (ID cards, branded t-shirts, uniforms) would be needed to keep motivated. Similar to findings in other settings a quarter of CSWs requested supplies and equipment

such as bars of soap, rain gear, backpacks, and gardening equipment, nominal investments compared to regular incentives.[139] Active surveillance programs requiring more hours can circumvent monetary incentives by pairing with education or labor interventions to provide preferential placement. Over 35% of CSWs noted that a pathway to education and employment would be a powerful motivator. In Liberia, CSWs are often favored for paid term work for health promotion and vaccination campaigns.

Another considerable portion of the budget (an estimated 25% in Liberia) for an integrated program is dedicated to direct (routine monthly payments) and secondary (modest supplements for travel outside county and supplies) incentives. At 30 USD per month, nearly 60% of CSWs reported they inadequately compensated for their work, and more than a quarter listed the lack of incentive as a major challenge. Part of the issue is the fragmentation of implementation in community interventions. Many CSWs are employed by multiple programs and provided different levels of compensation. When the incentive does not provide motivation, the quality of the data will suffer.[139]

3.5.1 Towards a Typology

Contributing to the challenge in developing and sustaining CEBS programs has been the lack of consensus on program activities, and structure.[93] Community surveillance programs have many formulations, ranging from passive to active surveillance, formal event-based reporting to awareness and self-referral. CEBS programs are tailored to a given disease and setting, complicating the sharing of best practices and adaptation to emerging health threats.

In Figure 3-5 below, we propose a typology of CEBS programs on the dimensions of organizational capacity and desired sensitivity. We define capacity as the "ability to perform the defined functions effectively, efficiently and sustainability and so the functions contribute to the mission, policies and strategic objectives of the health system".[140] Organizational capacity also includes the competency of staff to manage the program, ability to translate the data, financial resources, and leadership.

The desired sensitivity is dependent mainly on disease characteristics. Diseases which are high case fatality, highly infectious, or are targeted for elimination are suitable targets for a high sensitivity program. Conversely, conditions which are highly prevalent and contribute to a high proportion of the overall disease burden but have a low morbidity/mortality rate are appropriate for lower sensitivity approaches.

The four archetypes outlined by these dimensions are:

Awareness programs are passive surveillance, and do not have any frontline surveillance workers. As a result, these programs require low capacity and provide a modest increase in sensitivity through health facility and hotline reporting. They are typically intended to increase linkage to care between the community and the health system. Awareness can be conducted passively through mass media, or through health promotion structures, and targeted at the general population or sentinel sites such as schools, business, and markets.

Community-driven programs are also passive, but recruit key informants to increase sensitivity without burdening the health system. These programs rely on community mobilization, and positive relationships between the local health facility and

community are a prerequisite. As many key informants will report passively and have little training, community driven programs are best for conditions with simple triggers and low stigma. Allows communities to tailor the message and can be adapted to a local context.

Routine programs can be active or passive, and employ trained cadres of frontline surveillance workers. The management the cadre and use of the resulting information typically requires substantial technical and organizational capacity to manage. Establishing routine training and supervision pathways allow for reporting multiple disease triggers with more complicated syndromes. These types of programs are responsive to changing environments, as new triggers can be added in response to new public health risks.

Active response programs use trained cadres of frontline surveillance workers to actively identify disease conditions. Active surveillance activities often include house-to-house disease identification, reporting on disease vectors, and a basic response role. Elimination and eradication programs often use this strategy. These programs achieve high sensitivity, but are intensive and can only be maintained by local govenments for short periods of time. When cases are detected, there is a pathway for immediate action. Routine programs can be scaled to active response.

Figure 3-5. Typology of Community Event-Based Surveillance

		Awareness Increase linkage to care for severe disease, combat mis-information and stigma, and disseminate risk reduction and home treatment information.	**Community-driven** Engage communities in passive self-reporting conditions of local public health concern	**Routine** Sustained increase in sensitivity of routinely monitored diseases or conditions, especially incorporating response measures	**Active response** Substantially increase sensitivity of the disease surveillance system during an outbreak, or as part of an elimination/eradication campaign
Individual		Public-at-large: relies on linkage to health facilities or hotlines which are open to the public	Key informants: community members who are influential or representative of a certain segment of the community. May benefit from recruiting diverse backgrounds. Minimal capability required.	Formal or informal employment of community members. Often full or near full-time position, with supplemental health related duties. May require literacy benchmarks and specific demographic requirements.	Formal employment of community members or local health workers. Experience in health delivery, education, or past experience as a CHW is preferred
Community		Can improve health literacy and combat mistrust in the health system. Works best for diseases of high local prevalence or community impact	Requires active community engagement and dialogue. Reinforce role of CSW and recognize their contribution, and incorporate feedback into program evaluation and adaptation	In addition, Transportation barriers may become problematic due to routine reporting	In addition, requires a robust health messaging campaign and high level of trust in the health system
Health System	**Finances**	Relatively inexpensive; ongoing costs are limited to dissemination methods	Significant start-up costs to recruit and train key informants, with minor ongoing costs for refresher training	Requires ongoing supervision (and perhaps incentives and transportation). Expensive to maintain in a vertical program, but can incur significant cost savings when integrated into a large community program	Vertical program which can be expensive to sustain for a large geographic area or long timespan
	Organizational Capacity	Requires understanding of social determinants, knowledge, attitude, and perceptions of the disease. Can be quickly spun up and targetted at specific populations	In addition, requires ability to maintain strong community partnerships, and capacity to apapt and respond to community concerns. Periodic refresher trainings may be required, especially for diseases of low prevalence	In addition, requires strong surveillance structures and reporting systems to process and use data. Frequenct supervision and training required, often integrated into community programs	In addition, requires ability to respond to identified health threats, ability to absorb and use large amounds of data, mobilize resources, and coordinate with regional efforts
Program Design	**Surveillance Activities**	Outreach activities through diverse media to promote passive surveillance through presentation at the health facility. May self-report through direct hotlines	Community-driven passive reporting, often through the health facility and in irregular as-needed intervals	Routine reporting (weekly/month), often through the health facility. May include rudimentary response activities such as basic treatment or vector control	Active surveillance, often including house to house case finding. Often will include response activities, and detected cases may spur campaigns
	Triggers	Relies on easily identifiable signs and symptoms with high PPV to motivate reporting behavior	Not suited to stigmatized conditions. Best focused on a few select triggers.	Can report on a variety of endemic or epidemic-potential diseases	Very few disease triggers, emphasizing sensitivity
	Incentives	None. Relies on passive reporting and behavior change	Minimal incentives which may be non-monetary. Non-monetary incentives should emphasize and recognize role as a community leader	Often includes a minimal incentive paired with materials, transportation incentives, and	Monetary incentives recommended to compensate for rigorous active surveillance and response activities

This typology may be useful in determining whether proposed activities correspond to the with the required sensitivity and the existing organizational capacity in the area. This typology also helps clarify the rationale for varying CEBS formulation from region to region. For instance, a county may choose to implement a routine CEBS activity in the areas with the lowest health facility accessibility and implement a community-driven activity in urban areas.

Based on this typology, the CEBS pilot would likely fall under the active response category. This distinction is reasonable, as the program was implemented during the tail-end of the Ebola epidemic and focused on early warning of EIDs and rapid response to potential cases. The nascent surveillance system and decreasing financial funding make it unlikely a program with this design will be sustainable, and the tasks for addressing endemic and reportable conditions are different. The options for Liberia are to transition to a "routine" or "community-driven " program, or some hybrid of the two.

3.5.2 Limitations and Next Steps

The CEBS program described in this paper was designed during an emergency and ran for less than a year, and thus may not have been able to achieve a steady state in reporting and structures. Further, the surveillance system in Liberia was not fully implemented at the time of the project, resulting in parallel structures and problems with identifying cases between databases. Without an independent and external source for identifying false negatives, such as household level data, we were not able to establish the marginal coverage boost contributed by the program. The short duration of the program and unique circumstances of implementation limit our ability to concretely establish predictions of sustainability, or externally generalize these results to other settings. Further research should focus on developing a quantitative assessment of the impact of CEBS programs on disease surveillance.

3.6 CONCLUSIONS

Community event-based surveillance programs in Liberia were a useful tool in increasing the coverage of the disease surveillance system in response to a serious Ebola

epidemic. While we were not able to externally benchmark sensitivity, the CEBS program accounted for 31.5% of non-EVD cases in the national surveillance system. CEBS provided a secondary benefit by providing community engagement in the surveillance system and allows disease surveillance to adapt to changing health threats more quickly.

The sustainability of CEBS programs is challenging in multiple dimensions, most notably political support, organizational capacity, and financial stability. As a high intensity elimination-based system, the CEBS program in Liberia costs 3.69 USD per capita. If transitioned to a routine program and fully integrated into the broader community health service, the additional cost for CEBS could be reduced to a more affordable $0.55 USD per capita by cost sharing training and supervision activities with ongoing community programs, accounting for 2.9% of domestic expenditure on health. A better understanding of CEBS activities and the archetypes they fall into can aid in identifying best practices and promote discussions on which activities are most appropriate for the context.

4 Determinants of Community Health Worker Performance in Community Disease Surveillance in Liberia

4.1 Abstract

Background: Stopping outbreaks in low-income settings requires a sensitive, timely, and representative disease surveillance system. Community-event based surveillance (CEBS) programs were piloted in Liberia during the tail end of the 2014-2016 EVD epidemic to increase sensitivity by extending the surveillance apparatus to frontline community-level surveillance workers (CSWs). CSWs referred potential cases to the health facility and provided alerts on adverse health events. We explore the individual and program factors which may impact performance of CSWs in the detection and referral of health events in the CEBS program in Liberia.

Methods: We use data from a cross-sectional survey of CSWs performed in November 2016, after the end of the 21-week surveillance program. CSW performance was defined by a primary outcome indicator (reporting one trigger during the program period) and three quality indicators: trigger recall, process knowledge, and the number of information sources. Determinants included individual, community, and health facility level factors. Association between determinants and performance was assessed using logistic regression, ordinal logistic regression, and partial proportional odds models and 90% confidence intervals.

Results: Approximately 40% of CSWs in our sample reported during the program period. There was statistically significant variation across counties for each of the four

performance indicators, suggesting influence of unobserved variables such as differently underlying endemic burden of disease, or health system factors such as underreporting. Reporting at least one trigger during the program period was positively associated with proximity to the health facility (OR=0.30, 95%CI 0.17-0.52), and was not significantly associated with the process indicators. CSWs who were satisfied with their incentive were more likely to recall triggers (OR= 2.05, 95%CI 1.39-3.04), recall program protocol (OR=1.65, 95%CI 1.645-2.40) and have more information sources (OR=1.7, 95%CI 1.16-2.50). CSWs who reported good relationships with their supervisors also performed better in these three indicators. A high burden of supervision negatively impacted the number of CSW information sources (OR=0.59, 95%CI 0.35-0.99).

Conclusions: For the sampled CSWs in the Liberia CEBS pilot, CSWs at peak performance were trusted by community, positive relationships with supervisors, satisfied with incentives, and were close to a health facility. Transportation barriers continue to be a significant challenge for reporting. Knowledge of the program protocol can be improved through incentivization, recognition, and quality supervision. However, the lack of correlation and common explanatory variables suggest the driver of quantity and quality for the sampled population may be unique. This suggests best practices for maximizing performance of CSWs should vary based on context, desired sensitivity, and capacity. These findings can inform the design and management of similar programs in other settings and provide future directions for the study of CSW performance in community surveillance programs.

4.2 INTRODUCTION

Community health worker (CHW) programs often employ detection and referral of health events as a core activity.[98,101,102] When integrated into a national disease surveillance system, these activities offer improvements to timeliness and sensitivity and provide actionable information in populations with limited access to formal health care.[87] When constructed in a participatory manner, these programs also engage communities in the health system, improve health care utilization, and promote a better environment for risk communication.[94,141]

The effectiveness of community surveillance depends heavily on the performance of frontline personnel (CHWs). Rowe et al. (2005) suggest determinants of performance of community workers fall into two categories: interventions (e.g., training, supervision) and individual characteristics (e.g., CHW age, gender).[142] The objective of this study is to estimate the relative effect of these determinants on the performance of community health workers engaged in a community surveillance program in Liberia. The Liberian CEBS program was put into practice during the 2014-2016 West African Ebola Epidemic where timely detection at the community level was paramount in combatting the spread of disease. Implementation of the CEBS program also coincided with the relaunch of the national community health worker program, and the results of this study will inform the ongoing development of CEBS programs as a core building block in the national surveillance system.

4.2.1 Liberian Context

Fourteen years of civil war devastated infrastructure and left Liberia among the poorest countries in the world. The United Nations Development Program categorizes

Liberia as a least developed country, ranking 177 of 188 countries in the Human Development Index in 2015.[143] The 2014-2016 West African Ebola epidemic compounded existing fragilities in the health sector, further eroding public trust in the health system.[127] Capacity of service delivery from health facilities in the county remains weak as of 2017; Liberia has 1.7 health facilities (public and private) per 10,000 persons compared to the WHO benchmark of two, and utilization rates of public sector health facilities are one outpatient visit per person per year (OECD average is six, with a regional target in West Africa of five).[144,145] Outside of urban areas, private sector care provision is extremely limited. Among public facilities, only 11% of facilities have an emergency transport vehicle, and only about 1 in 2 are ready to provide general care services.[144] Overall, delivery of health services to remote communities is extremely poor, with some communities over 8 hours from the nearest health facility.[146]

CEBS was introduced as a core function of the Integrated Disease Surveillance and Response (IDSR) program in 2016, a direct response to the 2014-2016 West African Ebola epidemic.[131,147] Under-reporting of Ebola (estimated up to 40% of cases during the epidemic), poor health facility utilization, porous borders, and indications of an outbreak driven by community-level dynamics highlighted the ongoing need for community-level surveillance structures.[24,82,148]

The Ministry of Health implemented CEBS programs in partnership with a consortium of NGOs. The first and most extensive of these were implemented by the International Organization for Migration (IOM) during the tail-end of the epidemic in early 2016. At the time of implementation, most subnational surveillance staff were newly

hired, and health facility clinicians were recently trained in the new surveillance protocols. The rapid start-up, unstable funding, and narrow goals resulted in a program window one year. These limitations were used advantageously by treating this program as a pilot to guide the scaling of CEBS nationally. Lessons learned from the IOM project informed the community health policy and the development of National CEBS Technical Guidelines which were integrated into the national community health program.[133]

4.2.2 CHW Performance Considerations in Community Event-Based Surveillance

CEBS is a specialized referral activity involving the collection of information on events of public health concern.[90,149] As described in Paper 2, the design of CEBS program can differ based on context and goals. For routine and active response programs which require a trained, formal cadre, event-based surveillance introduces a unique structural burden on the performance of frontline workers.

The community case definitions can range from straightforward signs to a constellation of non-specific syndromes.[87] These definitions are sometimes purposefully amorphous to encourage reporting of unusual circumstances indicative of emerging infectious disease. These increasingly popular unstructured or semi-structured definitions demand a high level of competency from frontline workers, as well as engagement with health facility staff to understand how to classify rumors. If sucessful, this can also be useful in indigenous communities where perceived supernatural etiology may otherwise result in suppressed reporting.

There is a substantial time investment required from health facility staff to manage, supervise, and provide feedback specific to CEBS.[150] In routine programs, direct

supervision is conducted by clinicians, who may not have the epidemiological background and local knowledge necessary to provide mentorship in case detection and community entry. Mentorship in CEBS also presents a challenge; though case finding is a constant activity, focusing on low prevalence conditions leads to fewer opportunities to exercise reporting, receive feedback and correct errors.

Shifting the responsibility for community surveillance from the health facility can result in burdening communities with logistical constraints.[139,151] Community surveillance workers may frequently travel to complete their duties; often assisting in the transport of sick patients or to receive supervision and training. While the burden varies with population coverage and diseases of interest, these logistical and operational obstacles present a difficulty sustaining a cadre of high performing staff.

Referrals are the first step in a broader public health response, in addition to individual treatment and case management. As a result, most CEBS programs demand immediate event-level information, rather than the weekly or monthly aggregated indicator data commonly collected at the community level. Combined with the preference towards maximizing sensitivity and minimizing false negatives, this can result in a torrent of information at the national level which is challenging to parse. If these data are not used, and in turn demanded at high quality, performance at all levels is likely to decline.

In time of active response to a health threat, community surveillance workers may serve as a conduit between the health system and the community. In this role, community surveillance workers may be tasked with health promotion, community

engagement, and mobilization, in addition to active surveillance activities such as contact tracing and house to house case finding. In this paper, we focus on the performance during routine reporting, as active reporting incentives and motivations may be significantly different.

4.2.3 Defining and Conceptualizing CHW Performance in CEBS

As shown in the typology in paper 2, community surveillance activities are not the sole province of formally trained health workers. Context informs design. Broad approaches are appropriate in many contexts, such as educating community members *en masse* to increase general awareness of disease conditions. A more targeted approach is to recruit key informants in the community; school teachers, pharmacists, livestock handlers, and environmental technicians. In Liberia's CEBS program, community members are recruited, trained, supervised, and given a $30 incentive per month. To distinguish these community members from health facility staff and highlight the non-employee legal status, they are designated community health volunteers (CHVs). Community Health Assistants (CHAs) are a planned cadre of community members who will participate in a broader range of health services and are given a larger $70 per month incentive package (minimum wage is $4 per day for unskilled workers). To simplify our discussion and distinguish this cadre from community workers with a broader package of services as described in literature, we will use community surveillance worker (CSW) as a holistic term for frontline staff providing primarily surveillance services.

Ideally, performance would be measured in terms of marginal sensitivity and timeliness benefits. We cannot measure timeliness directly due to the lack of comparison

and reporting dates, though we are aware that during implementation health facilities reported weekly while communities reported immediately. Instead, we focus on the elements of sensitivity, with our operational definition of CSW performance of "high quality of reporting through multiple rumor sources, knowledge of community triggers, and knowledge of program process, combined with a high quantity of reporting determined by history of reporting disease to the health facility." We define performance as the ability of the CSW to actively identify signs of reportable conditions in the community and notify the health facility appropriately (Figure 1-1). Accordingly, the primary outcome indicator is reporting any disease during the program period. Process indicators of performance are (1) proportion of community case definitions recalled, (2) proportion of protocol steps recalled, and (3) number of sources of health rumors utilized in the community. We expect the process indicators to be correlated with the output indicator and together result in high quality, sensitive community reporting.

4.2.4 Health System Context

Health system context, taken as a combination of both the "hardware" of fundamental functions of financing, medical products, information systems, human resources, service delivery; and "software" – ideas and interests, means, norms, and relationships between actors; have broad impacts on CSW performance.[152] Most system-level factors influence program performance indirectly. Leadership which prioritizes community programs can readily reallocate resources to community programs. Use and demand for surveillance data can prompt measures to improve data quality and supervision. An organization-wide appreciation and recognition of the contributions of CSWs provide two-way

accountability.[141,153] In contrast, disorganized health systems result in frustrating delays in pay, demotivating apathy, and inaction.[20] These effects are difficult to isolate, and estimating their marginal effect requires rigorous study.

In Liberia, health facilities are tasked with oversight and supervision of CSWs and interface with the community. Supervision of CSWs is the responsibility of the Officer-In-Charge (OIC), the head clinician who is also primarily responsible for service delivery and daily operation. The workload of the OIC is a concern; health facilities with overburdened staff who are not incentivized for CEBS services may deprioritize community surveillance in favor of clinical duties. Liberia plans to recruit clinicians to focus solely on supervision of community workers, including CSWs, to reduce the workload on the OIC. The overall community satisfaction with service delivery is also a focus; responsive health sectors reduce stigma and promote care-seeking behaviors, increasing social standing, and utilization of CSWs.[154,155] Community members are unlikely to follow through on a referral if health facilities provide poor quality of care and have frequent drug stock-outs and long wait times.

4.2.5 Community Context

Community context encompasses a broad range of community-level attributes ranging from the built environment to ethnomedical beliefs and values. We highlight two pertinent to community surveillance programs in Liberia: geography and social standing. Geography plays a particularly large role; transportation barriers are a commonly cited performance challenge by CSWs.[156–158] The issue is exacerbated when screening for epidemic-prone disease in rural areas, essentially shifting the transportation burden from

the health facility clinicians to the CSW. The social standing of CSWs within the community is a frequently named driver for participation in community health programs.[159] Non-monetary incentives such as branded materials, support for travel, and the ability to navigate the local health system serve to increase social standing.[101,153]

4.2.6 Individual Inputs

Socioeconomic background of CSWs in community programs can be regulated by defining the recruitment pool and eligibility criteria. However, there is limited evidence linking demographics to performance in community surveillance programs. Bhattacharji et al. (1986) found that performance in a community program encompassing referral activities in India was lower among CSWs with more years of education, theorizing that education represented a barrier to visiting poorer and lower caste homes.[160] This effect was mitigated when the catchment area size was small, and the CSW had experience in delivering programs. Viswanathan et al. (2012) found female CSWs increased utilization of reproductive health services in Afghanistan, hypothesizing community members preferred female CSWs and females were better suited to encourage other women to utilize services.[161] These two examples share a commonality in describing a mechanism in which demographics do not directly impact performance. Instead, the relationship is modified by the aggregated set of differences between the CSW and the community and the specific activities in the program. This likely holds in community surveillance programs; the impact of demographics on performance will be modified by choice of target diseases and community context.

Acquired characteristics have a more evident impact. For instance, CSWs with prior experience tend to perform better, whether through higher levels of competence, self-selection of individuals who understand responsibilities, or better interpersonal relationships with health facility staff. Multiple studies have found altruism is a strong motivator to perform well, though it would be challenging to screen on individual motivations.[162,163]

4.2.7 Program Design Inputs

Aligning programs with local context can improve overall program performance. Alternatively, designs featuring complex reporting requirements and large catchment area sizes can result in reduced data quality and timeliness, and reduced participation in the most difficult tasks.[104] Designing CEBS programs to maximize performance is an exploration of compromises. The most obvious of these is the number and type of target conditions and the intricacy of their respective community case definitions. Investments in supervision and CSW provisions can improve performance as well. Job aids and mobile devices can reduce CSW burden and engender feelings of competency.[136,164] Direct monetary incentives are contentious, and literature is divided on its impact on performance. Monetary incentives can reduce attrition and improve performance, especially among CSWs who use the income as the primary resource to support their family.[136,159,165] Not providing incentives may burden families who must support the CSW.[163] However, incentives may have unintended effects, such as favoring incentivized activities or eroding innate altruistic ethos.[166–169] The association between monetary incentives and performance is mixed, and modified by the context, design of incentives,

type of cadres, services performed, and program goals[20,170] Programs frequently rely on training and supervision as the core strategy to improve performance. Knowledge gained through training is reemphasized during supportive supervision and mentorship by health facility clinicians, providing valuable feedback which can provide short-term benefits.[151,171] Though these benefits have proven difficult to realize, the evidence suggests that community support combined with quality, practice-focused training is effective at improving performance.[142,172,173]

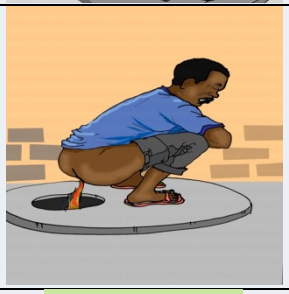
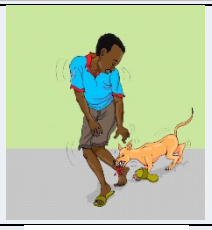
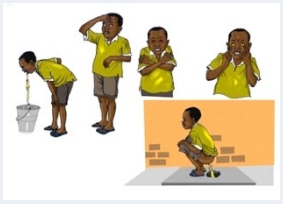
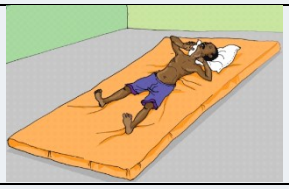
4.3 METHODS

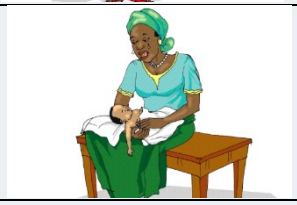
4.3.1 Liberia Community Event-Based Surveillance Program

The CEBS program supported by the International Organization for Migration operated between April and September of 2016. The goal was to increase sensitivity near the porous land border to prevent re-infection of Ebola from neighboring countries. The eight border counties account for approximately 36.5% of the population of Liberia (Appendix Table 2). Table 4-1 presents the community case definitions (or triggers) which were constructed by the Liberia Ministry of Health (MOH) based on near term health priorities.

Table 4-1. Community Case Definitions and Job Aids

IDSR Condition	CEBS Community Case Definition	Job Aid
Acute Flaccid Paralysis (Poliomyelitis)	Any person with weakness in the legs and arms or not able to walk	

Acute Watery diarrhea (Cholera)	Running stomach. Any -person passing three (3) or more water pu-pu within one day.	
Acute bloody diarrhea (Shigellosis)	*Diarrhea* with blood (pu-pu with blood)-Any person passing bloody pu-pu or slimy (slippery) pu-pu with stomach pain	
Human Rabies	Any person who is bitten by a dog or other animal	
Measles	Any person with hot skin (fever) and spot-spot (rash)	
Ebola, Lassa *Fever* , & Yellow Fever	Any person who has -fever and two or more other symptoms (headaches; vomiting; runny stomach; weak in the body, yellow eyes), or who died after serious sickness with fever and bleeding.	
Meningitis	Any person with hot skin (fever) and stiff neck.	
Maternal Death	Big belly death, Woman who dies with -big belly or within 42 days (six weeks) after the baby is born or when the belly move.	

Neonatal tetanus	Jerking Sickness, Baby who is normal at birth, then after two days is not able to suck and starts jerking	
Neonatal Death	Young baby *death*, Baby who dies at birth or within 28 days (four weeks) after birth	
Unexplained Cluster of events or disease	Unknown health problems grouped together. Any health problem that you don't know about that is happening to many, many people or animals in the same community.	
Unexplained death	Any death in human or group of animals that you don't know why it happened	

One CSW was employed for roughly every 100 households (500 persons), totaling 2972 workers in the program area. Selection criteria for CSWs included (1) permanent residency within the community (2) age between 18 and 50, and (3) a basic level of literacy (defined by a 6th-grade reading and writing equivalency). Community Health Committees (CHCs) nominated eligible individuals, and from this pool, the CSW was selected by the officer-in-charge. Many CSWs were previously community health volunteers, though this was not a requirement. A monthly incentive of $30 and transportation allowance during training and monthly coordination meetings were provided, in addition to logistical supplies including rain gear and backpacks. Where active, Community Health Committees provided a venue for CSWs to participate in monthly health talks and provide feedback to community leaders on alert outcomes. The officer-in-charge or designate was responsible for supervision on a routine basis. See Chapter 3 for more detailed implementation information.

4.3.2 Study design and context

Data for this study were derived from a cross-sectional evaluation conducted between October and November of 2016. We administered a multistage cluster survey in three randomly selected counties. Data collection occurred at each of the four stages of the health system: county, district, health facility, and community. Simple random sampling determined clusters and respondents. The number of interviews was predetermined based on the available resources. See Chapter 3 for more details on sampling. The interview tool was adapted from the Liberia IDSR Supervision Toolset and MEASURE Evaluations' Performance of Routine Information System Management (PRISM) survey.[38] The questionnaire was designed to examine implementation and sustainability concerns identified by the Technical Working Group. The CEBS Technical Working Group validated the final survey tool. The International Organization for Migration field staff were recruited as interviewers with knowledge of the local tribal languages (over 10 in the three counties). Though IoM implemented the program, field staff were not in direct supervisory positions over the respondents. and were employed through local NGOs. Though all respondents were expected to have a minimum English literacy equivalent to a 6th-grade level, interviewers were coached in interpreting questions into Liberian Kreyol if the respondent did not understand the question. Tablets with OpenDataKit were used for data entry. During the project period, the International Organization for Migration administered a database containing alerts and their outcomes for each CSW. This database was independent of the Ministry of Health information system. This CEBS database tracked the full history of alerts through the

reporting chain, from initial identification, reception at the health facility, and whether the alert matched both the CEBS and IDSR case definitions. Each report was verified by an IOM affiliate surveillance field officer and cross-signed by the community, health facility, and district surveillance officers.

4.3.3 Variable Construction

Outcomes of Interest

We identified four performance metrics of interest, three process indicators, and one outcome indicator:

- Ever reported during the program period: Each 250-500-person community catchment area was expected to generate at least one alert over a 23-week period due to the expected high sensitivity of the case definitions. A subset of diseases available in the national HMIS system indicates the average community in Liberia would have an average of 2.18 per 375 persons during the 23 week program period (Table 7-3). This is a very conservative estimate, as not all disease conditions are available in HMIS, and HMIS only reports cases which were seen in a health facility. We assume then, that communities without any alerts likely indicate a failure of the CSW to identify or report a case. The total number of alerts from each community was not interpreted as a performance metric, due to the influence of ongoing epidemics. Data for this indicator was taken from IOM's independent data source of alerts, verified by field staff.
- Number of community case definitions recalled: Job aids were provided to all CSWs to aid in the verification of suspect triggers in the community. CSWs who

have been able to internalize definitions may be more likely to have been involved in active case finding and have more success in identifying potential triggers in the community. The number of definitions recalled was categorized as very low (0%-25%), low (26%-50%), medium (51%-75%), and high (76%-100%).

- Number of reporting processes recalled: CSWs were taught a rudimentary four step alert identification process: verifying the suspect case meets the community case definition, documenting and reporting the case to the health facility, referring the patient and assisting in transportation, and receiving feedback from the health facility and providing feedback to the community.
- Number of health rumor sources: Community resource mapping provided identified sources of health rumors in the community, such as businesses, schools, peers, religious institutions, and community structures. CSWs who can draw from multiple types of informants are more likely to detect cases in their catchment community. CSWs with 5 or more rumor sources were analyzed together to account for urban communities with a large variety of sources.

The PRISM framework and survey tool were adapted for the focus on the community level and real-time data collection. PRISM uses three categories to describe the success of information system interventions in creating quality data for public health action: (1) organizational determinants, (2) technical determinants, and (3) behavioral determinants. In the survey, we included organization characteristics such as supervision, mentorship, coordination, and feedback; technical determinants such as cell phone coverage, internet and computers, transportation barriers, and paper form stock; and behavioral

determinants such as data use, perceptions of stigma, culture of data, trust and respect, and data demand. Ancillary data elements included the respondent's background characteristics, and implementation issues such as incentives, challenges, and process. Notably, direct measures of motivation are not included. However, some of these data elements would affect motivation.

Construction of Performance Determinants

All determinants were self-reported by either CSWs or OICs. CSW education was dichotomized as "high"; high school education or greater or "low": no schooling or any education lower than high school. Age of CSWs was grouped into ten-year increments. CSWs with any income excluding incentive payments were categorized as having a supplemental income. Participation in any previous community health program or activity was categorized as prior experience in providing health services. Phone ownership was defined as owning or access to a functioning phone which could send and receives texts. However, this did not consider whether CSWs had funds or scratch cards to make calls or connect to a cellular network while within the village. Walking time was self-assessed as either more than an hour or less than an hour's walk from the health facility. Nearly three-fourths of CSWs reported that walking was their primary mode of transportation when traveling to the health facility.

A battery of Likert questions was given to respondents to assess perceptions and attitudes towards program activities. These Likert questions were adapted from the PRISM tool, designed to assess the culture of data. All questions were scored on a scale of Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree. Questions related to

supervision, trust, and incentives were considered individually to explore their policy impact. The relationship between the CSW and community was assessed in two ways. CSWs were asked to assess whether people trusted and talked to them about their health conditions. Those who agreed with this statement were categorized as having a trusting relationship. We also coded a trust variable from semi-structured answers indicating the top three challenges in completing CEBS activities. CSWs who indicated trust or respect as a major challenge was recoded as not having a trusting relationship. Incentive satisfaction was assessed based on CSW perceptions of compensation. CSWs who agreed to the statement "I feel adequately compensated for my work" were categorized as being satisfied with the $30 incentive.

We used exploratory factor analysis on the remaining questions in the tool to reduce overall dimensionality while preserving the information by extracting latent factors which may be associated with CSW performance. Results of the factor analysis were rotated with an oblique Promax procedure, which allows inter-factor correlation. The first factor accounted for 65.7% of the total variance, with an eigenvalue of 3.89. All other factors were discarded as their eigenvalues were less than 1. The extracted factor loaded heavily on the relationship to health facility and field supervisors, which we interpret as supervision validation and respect. As the relationship with the health facility supervisor explained the majority of variance, the variable was used directly in the model to simplify the interpretation of results. See the appendix tables for EFA results.

Health facility-level factors were obtained from OIC interviews. These included self-reports of whether the health facility maintains a list of the contact information or

displays graphs of priority disease trends in the catchment area. Supervision frequency was determined based on the communication frequency between the CSW and OIC. Weekly (mandated by the program) or greater frequency was categorized as "frequent." High burden of supervision was identified by OICs who agreed to the statement "I feel that supervision and mentorship of CSWs is a burden."

4.3.4 Statistical Analysis

Proportion distributions were estimated for the CSW and health facilities characteristics. The data was unweighted as the intent of the model is to measure the association between determinants and CSW performance rather than conduct a representative descriptive evaluation CSWs in the program.[174] Though we do not suspect or measure for sources of ~~heterskedasticity~~heteroskedasticity or ~~heteregenous~~heterogenous effects, weighted models which take into account survey design effects are presented in the Appendices for comparison. Variables of interest were imputed using Multivariate Imputation using Chained Equations (MICE) procedure, which sequentially imputes variables based on specified distributions, and does not assume assuming normality for all variables. Bivariate and multivariate analyses were performed for these factors. The outcome of ever reported (y_r)was modelled as a logistic regression using the logit command in Stata 13 SE. The outcomes for recalled triggers and processes were modelled using the ordered logistic regression. Ordered logistic regression assumes proportional odds; where the odds is constrained across categories. Ordered logistic regression was modelled using the ologit package in Stata 13. The proportional odds assumption was tested using a Brant Test for Parallel Regression Assumption, which

provides a χ^2 test with the null hypothesis that the parallel regression assumption is true, evaluated at a 95% confidence. For models which violate this assumption, variables were re-specified by collapsing unstable categories in the case of a small number of observations. If the assumption was still violated, a partial ordered logistic regression was used instead. This model relaxes the proportional odds constraint on variables which vary on values of the dependent variable but is more parsimonious than the fully unconstrained model. The partial proportional odds were modeled using the gologit2 package of Stata 13 SE.

Two models were specified for each performance outcome: A) models containing both health facility and community factors and B) models with only health facility factors. The primary comparison criteria was the Bayesian Information Criterion (BIC). Bayesian Information Criterion favors parsimonious models and is a more conservative test at smaller sample sizes compared to the Aikake Information Criterion. Lower BIC indicates a more informative model.

4.4 RESULTS

4.4.1 Sample Characteristics

Our study included 432 of the 3875 CSWs in the three target counties. The key characteristics of the CSWs sampling and breakdowns by performances indicator are shown in Table 4-2. The majority of CSWs in the sample (82%) were male; the median age was 36 years (x=36.9 s=10.2). Most had at least a high school education (66%), and two-thirds reported having another source of income. One-third of CSWs in~~e~~ the sample

resided more than an hour's walk to the health facility, similar to the household average estimated by the 2013 Liberia Demographic Health Survey.[175]

A higher than expected percentage of CSWs in our sample (19%) reported a lack of community trust presented a major challenge towards carrying out their CEBS responsibilities. The majority of CSWs reported an adequate level of satisfaction with their incentive (63%).

Table 4-2. Univariate and bivariate descriptive statistical for selected characteristics

Variable[1]	N (%)		Prop. Ever Reported	Avg. Process	Avg. Trigger	Avg. Info Sources
Total (n=432)	- -		0.42 (0.02)	1.74 (0.05)	6.38 (0.13)	2.82 (0.10)
CSW Level variables (n=432)						
Number of CSWs per county						
Bong	167	39%	0.66 (0.04)	1.77 (0.07)	6.34 (0.21)	3.01 (0.17)
Grand Cape Mount	146	34%	0.19 (0.03)	1.69 (0.08)	5.90 (0.21)	2.54 (0.15)
Lofa	119	28%	0.34 (0.04)	1.75 (0.09)	7.01 (0.25)	2.91 (0.19)
CSW Gender						
Male	353	82%	0.42 (0.03)	1.70 (0.05)	6.72 (0.34)	2.89 (0.24)
Female	79	18%	0.42 (0.06)	1.91 (0.11)	6.30 (0.14)	2.81 (0.11)
CSW Age						
<=35 years old	200	46%	0.35 (0.03)	1.75 (0.07)	6.12 (0.17)	2.69 (0.14)
>35 years old	232	54%	0.48 (0.03)	1.72 (0.06)	6.68 (0.20)	2.94 (0.14)
CSW Educational Level						
None	29	7%	0.52 (0.09)	2.03 (0.14)	7.08 (0.60)	4.00 (0.52)
Elementary	116	27%	0.49 (0.05)	1.69 (0.08)	6.07 (0.24)	2.86 (0.21)
High School	273	63%	0.37 (0.03)	1.74 (0.06)	6.43 (0.16)	2.70 (0.11)
College	13	3%	0.46 (0.14)	1.31 (0.21)	6.38 (0.80)	2.31 (0.31)
CSW has other source of Income						
Yes	294	68%	0.45 (0.03)	1.74 (0.06)	6.52 (0.16)	3.02 (0.13)
No	138	32%	0.36 (0.04)	1.73 (0.08)	6.07 (0.21)	2.40 (0.13)
CSW provides other health services[2]						
Yes	173	40%	0.42 (0.04)	1.77 (0.07)	6.72 (0.20)	2.91 (0.17)
No	258	60%	0.42 (0.03)	1.71 (0.06)	6.14 (0.17)	2.76 (0.12)
CSW has a phone						
Yes	289	67%	0.43 (0.03)	1.67 (0.05)	6.65 (0.16)	3.01 (0.13)
No	141	33%	0.39 (0.04)	1.88 (0.09)	5.82 (0.21)	2.44 (0.13)
CSW satisfied with incentive[3]						
Yes	266	63%	0.45 (0.03)	1.84 (0.06)	6.72 (0.17)	3.11 (0.14)
No	158	37%	0.36 (0.04)	1.56 (0.08)	5.80 (0.21)	2.34 (0.13)
Lack of trust between CSW/Community[4]						
Yes	80	19%	0.34 (0.05)	1.89 (0.12)	6.38 (0.14)	3.01 (0.24)
No	352	81%	0.43 (0.03)	1.70 (0.05)	6.35 (0.30)	2.78 (0.11)
Walk time to health facility						
More than 1 hour	285	66%	0.37 (0.03)	1.72 (0.06)	6.25 (0.22)	2.87 (0.13)
Less than 1 hour	146	34%	0.50 (0.04)	1.77 (0.08)	6.44 (0.16)	2.72 (0.16)
CSW feels HF Supervisor values/trust them						
Yes	242	56%	0.44 (0.03)	1.83 (0.06)	6.89 (0.18)	3.40 (0.15)
No	188	44%	0.39 (0.04)	1.62 (0.07)	5.73 (0.17)	2.08 (0.10)
HF Level variables (n=71)						
HF keeps a CSW registry						
Yes	402	96%	0.41 (0.02)	1.72 (0.05)	6.35 (0.13)	2.83 (0.10)
No	18	4%	0.52 (0.12)	1.99 (0.29)	6.92 (0.62)	2.70 (0.58)
HF graphs disease trends						
Yes	207	49%	0.36 (0.03)	1.70 (0.07)	6.30 (0.19)	2.80 (0.14)
No	213	51%	0.47 (0.03)	1.77 (0.07)	6.45 (0.18)	2.85 (0.15)
High Supervision Frequency[5]						
Yes	308	73%	0.38 (0.03)	1.71 (0.05)	6.37 (0.15)	2.82 (0.11)
No	112	27%	0.51 (0.05)	1.81 (0.09)	6.39 (0.26)	2.82 (0.22)
OIC is burdened by supervision for HF[3]						
Yes	89	24%	0.47 (0.05)	1.79 (0.10)	6.44 (0.27)	2.70 (0.23)
No	288	76%	0.40 (0.03)	1.72 (0.06)	6.35 (0.15)	2.86 (0.12)

Standard error in parantheses

[1] All data are unweighted and based on CSW and health facility clinician self-reports
[2] Other health services encompass any involvement in community health programs, often health promotion activities and vaccination campaigns
[3] Adequately compensated and high supervision burden was dichotomized as Yes = "Strongly Agree" or "Agree" and No = Neutral, Disagree, and Strongly Disagree responses
[4] Lack of trust was based on a Likert response indicated "disagree" or "strongly disagree" that the community trusts them, or indicated community trust as a top three challenge in performing CEBS duties
[5] High frequency indicates the CSW responded that supervision by the health facility occurred "Often" rather than "Sometimes' or "Rarely"

4.4.2 Multivariate Regressions

Based on BIC, Model 1 was superior for each performance metric (Table notes). We report the remaining results using this model (Model A), containing determinants from both community and health facility levels.

Determinants of Ever Reporting a Trigger

Overall, about 40% of CSWs ever reported an alert during the program period (Table 4-2). Reporting was not associated with any process indicators in the unadjusted bivariate analysis. CSWs with more than an hour's walk to the health facility were more than three times fewer odds to have reported a case during the program period (OR:0.306, p: <0.001) (Table 4-3). CSWs who indicated a trusting relationship between themselves and the community had nearly twice the odds to have no reports during the program (OR: 1.744, p: 0.073). An alternative source of income increased odds of reporting by approximately 50% (OR: 1.551, p: 0.89). We also found CSWs in Grand Cape Mount (OR: 0.089, p: <0.001) and Lofa (OR: 0.315, p: <0.001) were less likely to report

than CSWs in Bong. The large magnitude of effect for counties indicates unobserved variables are contributing variation towards reporting performance between counties.

Table 4-3. Determinants of CSW ever reporting during program

	Unadjusted Odds Ratio			Model A: Facility + Community[2]			Model B: Community Only[2]		
Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept	0.714	(0.61 , 0.84)	**0.001**	8.296	(2.04 , 33.74)	**0.013**	3.633	(1.30 , 10.18)	**0.039**
County									
Bong	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Grand Cape Mount	0.120	(0.08 , 0.19)	**<0.001**	0.089	(0.05 , 0.15)	**<0.001**	0.091	(0.06 , 0.15)	**<0.001**
Lofa	0.265	(0.17 , 0.40)	**<0.001**	0.315	(0.19 , 0.52)	**<0.001**	0.284	(0.18 , 0.45)	**<0.001**
Female CSW	1.005	(0.66 , 1.52)	0.983	0.784	(0.46 , 1.34)	0.456	0.775	(0.46 , 1.32)	0.428
CSW Age (10 year increment)	1.180	(1.01 , 1.38)	**0.077**	1.027	(0.84 , 1.25)	0.828	1.022	(0.84 , 1.24)	0.857
High CSW education[3]	0.615	(0.44 , 0.86)	**0.018**	0.669	(0.45 , 1.00)	0.102	0.654	(0.44 , 0.97)	**0.080**
CSW has other income	1.460	(1.03 , 2.07)	**0.076**	1.551	(1.01 , 2.37)	**0.089**	1.580	(1.04 , 2.41)	**0.074**
CSW provided prior health services[4]	0.989	(0.71 , 1.37)	0.954	1.178	(0.79 , 1.75)	0.498	1.162	(0.79 , 1.72)	0.529
CSW has a phone	1.153	(0.82 , 1.63)	0.497	0.985	(0.65 , 1.49)	0.951	0.998	(0.66 , 1.51)	0.993
CSW adequately compensated[5]	1.495	(1.06 , 2.10)	**0.052**	1.316	(0.88 , 1.97)	0.265	1.294	(0.87 , 1.93)	0.290
Walking time >1 hour to HF	0.594	(0.42 , 0.83)	**0.011**	0.306	(0.19 , 0.49)	**<0.001**	0.308	(0.19 , 0.49)	**<0.001**
Trust between CSW/Community[6]	1.509	(0.98 , 2.31)	0.113	1.744	(1.05 , 2.90)	**0.073**	1.717	(1.03 , 2.85)	**0.080**
CSW is validated by supervisor[7]	1.222	(0.88 , 1.69)	0.311	1.093	(0.74 , 1.62)	0.708	1.093	(0.74 , 1.61)	0.706
HF has a CSW registry	0.661	(0.30 , 1.45)	0.387	0.538	(0.20 , 1.47)	0.310			
HF displays graphs of disease trends	0.635	(0.46 , 0.88)	**0.022**	1.011	(0.67 , 1.52)	0.964			
Daily/weekly supervisor communication	0.606	(0.42 , 0.87)	**0.023**	0.716	(0.44 , 1.17)	0.263			
OIC is burdened by supervision[5]	1.380	(0.94 , 2.03)	0.170	0.869	(0.52 , 1.46)	0.655			
Number of CSW information sources[8]	1.039	(0.96 , 1.12)	0.419						
Number of recalled triggers[8]	1.022	(0.96 , 1.08)	0.553						
Number of recalled process steps[8]	0.975	(0.82 , 1.15)	0.800						

Outcome 1=any reported trigger by CSW during the program, 0=no triggers reported by CSW during the program

1. All data are unweighted and based on CSW and health facility clinician self-reports. See "Yes" responses from Table 4-2 for reference categories

2. Explained variance greater than unexplained variance overall, based on omnibus F-test p-value < 0.05, Model 1 was more informative (more explained variance), the difference in BIC $\chi 2=39.34$ (Model2-1)

3. High CSW education is defined as some high school education or greater

4. Other health services encompass any involvement in community health programs, often health promotion activities and vaccination campaigns

5. CSW incentive satisfaction and high supervision burden was dichotomized as Yes = "Strongly Agree" or "Agree" and No = Neutral, Disagree, and Strongly Disagree responses

6. Trust was based on a Likert response indicated "Agree" or "Strongly Agree" that the community trusts them, or indicated community trust as a top three challenge in performing CEBS duties

7. Supervisor validation is the extracted first factor from the exploratory factor analysis7High frequency indicates the CSW responded that supervision by the health facility occurred "Often" rather than "Sometimes' or "Rarely"

8. These variables correspond to other performance metrics and are not included in modeling

Determinants of Trigger Recall Performance

The average CSW was able to recall 6.4 community case definitions (Table 4-2), and less than 10% were able to recall all twelve. Female CSWs had 60% better odds of recalling triggers (OR: 1.600, p=0.079) (Table 4-4). Experience in providing other health services improved odds of recall by about half (OR: 1.523, p=0.029). CSWs with a phone were more likely to recall triggers (OR: 1.730, p=0.006). CSWs who felt adequately compensated (OR: 2.054, p<0.001) or felt their supervisor recognized and validated them (OR: 1.914, p<0.001) were nearly twice as likely to recall triggers.

Table 4-4. Determinants of recalling community trigger definitions

	Unadjusted Proportional ORs			Model A: Facility + Community[2,3]			Model B: Community Only[3]		
Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept 1[4]	0.165	(0.13 , 0.21)	**<0.001**	-0.635	(-1.70 , 0.43)	0.327	-0.146	(-0.97 , 0.67)	0.770
Intercept 2[4]	0.191	(0.03 , 0.35)	**0.049**	1.517	(0.45 , 2.58)	**0.019**	1.992	(1.16 , 2.83)	**<0.001**
Intercept 3[4]	1.861	(1.63 , 2.09)	**<0.001**	3.330	(2.24 , 4.42)	**<0.001**	3.796	(2.92 , 4.67)	**<0.001**
County									
Bong	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Grand Cape Mount	0.926	(0.66 , 1.31)	0.714	1.033	(0.71 , 1.51)	0.889	0.989	(0.69 , 1.42)	0.961
Lofa	1.593	(1.11 , 2.29)	**0.034**	1.791	(1.18 , 2.72)	**0.022**	1.651	(1.12 , 2.44)	**0.035**
Female CSW	1.205	(0.82 , 1.77)	0.423	1.600	(1.03 , 2.48)	**0.079**	1.532	(1.00 , 2.35)	0.102
CSW Age (10 year increment)	0.938	(0.82 , 1.08)	0.443	1.010	(0.86 , 1.18)	0.917	1.007	(0.86 , 1.18)	0.941
High CSW Education[5]	1.172	(0.86 , 1.60)	0.399	1.203	(0.87 , 1.67)	0.355	1.163	(0.84 , 1.61)	0.446
CSW has other income	1.178	(0.86 , 1.61)	0.384	1.189	(0.85 , 1.66)	0.391	1.196	(0.86 , 1.66)	0.372
CSW provides other health services[6]	1.363	(1.01 , 1.83)	**0.086**	1.523	(1.11 , 2.09)	**0.029**	1.512	(1.10 , 2.07)	**0.030**
CSW has a phone	1.758	(1.29 , 2.40)	**0.003**	1.730	(1.24 , 2.41)	**0.006**	1.736	(1.25 , 2.41)	**0.006**
CSW adequately compensated[7]	1.960	(1.44 , 2.67)	**<0.001**	2.157	(1.56 , 2.99)	**<0.001**	2.100	(1.52 , 2.90)	**<0.001**
Walking time >1 hour to HF	1.021	(0.75 , 1.38)	0.912	1.014	(0.72 , 1.43)	0.946	1.019	(0.72 , 1.43)	0.927
Trust between CSW/Community[8]	1.126	(0.78 , 1.64)	0.601	1.196	(0.57 , 1.23)	0.445	0.834	(0.57 , 1.23)	0.438
CSW is validated by supervisor[9]	2.129	(1.58 , 2.87)	**<0.001**	1.914	(1.40 , 2.62)	**0.001**	1.915	(1.40 , 2.61)	**0.001**
HF has a CSW registry	0.839	(0.41 , 1.74)	0.691	0.567	(0.26 , 1.26)	0.241			
HF displays graphs of disease trends	0.857	(0.64 , 1.15)	0.391	0.912	(0.65 , 1.27)	0.650			
Daily/weekly supervisor communication	1.120	(0.80 , 1.56)	0.577	0.989	(0.65 , 1.51)	0.967			
OIC is burdened by supervision[6]	1.018	(0.68 , 1.51)	0.942	1.112	(0.65 , 1.90)	0.740			
At least one reported case[10]	1.083	(0.81 , 1.45)	0.654						
Number of CSW information sources[10]	1.611	(1.48 , 1.75)	**<0.001**						
Number of recalled process steps[10]	1.492	(1.28 , 1.74)	**<0.001**						

Outcome variable is number of triggers recalled, aggregated into ordinal categories of 0 to 3, 4 to 6, 7 to 9, and 10-12

1. All data are unweighted and based on CSW and health facility clinician self-reports. See "Yes" responses from Table 4-2 for reference categories
2. Proportional odds assumption was rejected (Likelihood-ratio test vs. multinomial model $\chi2=265.37$, $p<0.001$); however modeling as partial proportional odds resulted in proportional odds for all variables except county. Only nominal differences were observed in estimates across the outcome. Ordinal model is presented for ease of interpretation. Model of partial proportional odds is given in the appendix for comparison.
3. An explained variance greater than unexplained variance overall, based on omnibus F-test p-value < 0.05, Model 1 was more informative (more explained variance), the difference in BIC $\chi2=106.0$(Model2-1)
4. Intercepts indicate cut points (sometimes considered thresholds) and are not directly used in model interpretation
5. High CSW education is defined as some high school education or greater
6. Other health services encompass any involvement in community health programs, often health promotion activities and vaccination campaigns
7. CSW incentive satisfaction and high supervision burden was dichotomized as Yes = "Strongly Agree" or "Agree" and No = Neutral, Disagree, and Strongly Disagree responses
8. Trust was based on a Likert response indicated "disagree" or "strongly disagree" that the community trusts them, or indicated community trust as a top three challenge in performing CEBS duties
9. Supervisor validation is the first factor of the EFA
10. These variables correspond to other performance metrics and are not included in modeling

Determinants of Protocol Recall

Table 4-5 shows the determinants of recalling the reporting protocol. CSWs recalled on average 1.74 steps of the 4-step protocol (verify, report, refer, feedback). CSWs with a phone were less likely to remember the protocol (OR: 0.599, p=0.011). CSWs who were satisfied with their compensation were more likely to remember process (OR: 1.642, p=0.011). Female CSWs were more likely to recall the protocol (OR: 1.534, p=0.091).

Table 4-5. Determinants CSW recall of the reporting process

	Unadjusted Proportional ORs			Model A: Facility + Community[2,3]			Model B: Community Only[3]		
Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept 1[4]	-2.339	(-2.67 , -2.01)	**<0.001**	-2.619	(-3.72 , -1.51)	**<0.001**	-1.844	(-2.83 , -0.86)	**<0.001**
Intercept 2[4]	-0.308	(-0.50 , -0.12)	**0.002**	-0.492	(-1.57 , 0.59)	0.454	0.272	(-0.69 , 1.23)	0.578
Intercept 3[4]	1.280	(1.05 , 1.51)	**<0.001**	1.172	(0.09 , 2.25)	**0.074**	1.924	(0.95 , 2.90)	**<0.001**
Intercept 4[4]	3.473	(2.92 , 4.02)	**<0.001**	3.420	(2.27 , 4.57)	**<0.001**	4.164	(3.07 , 5.26)	**<0.001**
County									
Bong	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Grand Cape Mount	0.839	(0.60 , 1.18)	0.397	0.907	(0.62 , 1.32)	0.668	0.888	(0.58 , 1.36)	0.582
Lofa	0.959	(0.67 , 1.37)	0.846	1.275	(0.85 , 1.91)	0.325	1.151	(0.73 , 1.82)	0.545
Female CSW	1.512	(1.04 , 2.19)	**0.068**	1.534	(1.01 , 2.33)	**0.091**	1.468	(0.90 , 2.39)	0.122
CSW Age (10 year increment)	1.087	(0.94 , 1.25)	0.329	1.122	(0.96 , 1.31)	0.230	1.120	(0.93 , 1.35)	0.230
High CSW Education[5]	0.914	(0.68 , 1.24)	0.624	0.969	(0.71 , 1.33)	0.871	0.922	(0.63 , 1.34)	0.670
CSW has other income	1.017	(0.75 , 1.38)	0.927	0.929	(0.67 , 1.30)	0.718	0.941	(0.63 , 1.40)	0.761
CSW provides other health services[6]	1.115	(0.83 , 1.49)	0.542	1.334	(0.98 , 1.82)	0.127	1.324	(0.92 , 1.91)	0.133
CSW has a phone	0.656	(0.48 , 0.90)	**0.028**	0.599	(0.43 , 0.84)	**0.011**	0.601	(0.40 , 0.89)	**0.012**
CSW adequately compensated[7]	1.661	(1.22 , 2.25)	**0.006**	1.642	(1.19 , 2.26)	**0.011**	1.585	(1.09 , 2.31)	**0.017**
Walking time >1 hour to HF	1.408	(0.96 , 2.07)	0.142	1.434	(0.97 , 2.13)	0.134	1.418	(0.88 , 2.27)	0.147
Trust between CSW/Community[8]	1.524	(1.14 , 2.04)	**0.018**	1.516	(1.11 , 2.07)	**0.027**	1.533	(1.06 , 2.21)	**0.023**
CSW is validated by supervisor[9]	0.882	(0.65 , 1.20)	0.502	0.844	(0.60 , 1.18)	0.409	0.844	(0.57 , 1.26)	0.406
HF has a CSW registry	0.620	(0.29 , 1.34)	0.307	0.452	(0.20 , 1.02)	0.109			
HF displays graphs of disease trends	0.851	(0.64 , 1.14)	0.361	0.969	(0.70 , 1.33)	0.871			
Daily/weekly supervisor communication	0.813	(0.59 , 1.13)	0.298	0.875	(0.60 , 1.28)	0.565			
OIC is burdened by supervision[6]	1.110	(0.78 , 1.58)	0.628	1.082	(0.71 , 1.65)	0.757			
At least one reported case[11]	0.978	(0.73 , 1.31)	0.902						
Number of CSW information sources[11]	1.370	(1.23 , 1.53)	**<0.001**						
Number of recalled triggers[11]	1.170	(1.11 , 1.24)	**<0.001**						

Outcome variable is the reported number of process steps recalled (Verify, Record, Report, Feedback) from 1 to 4

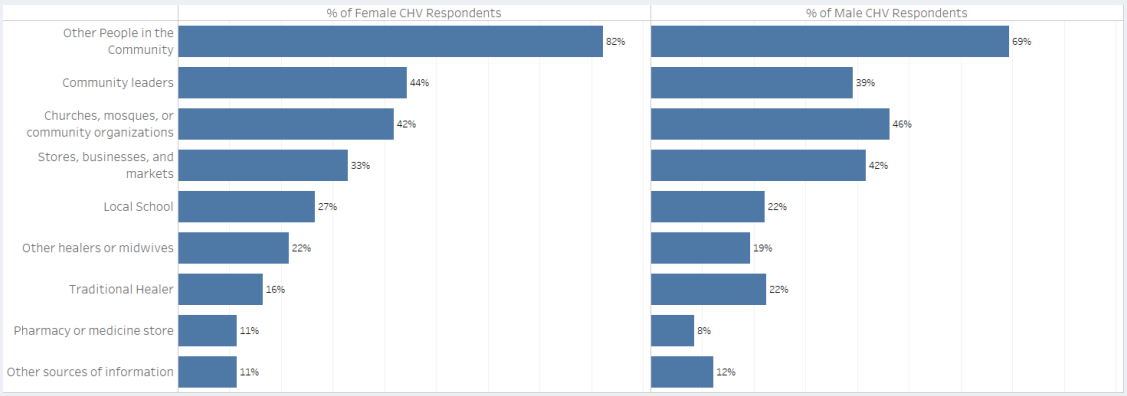
1. All data are unweighted and based on CSW and health facility clinician self-reports. See "Yes" responses from Table 4-2 for reference categories
2. Proportional odds assumption was rejected (Likelihood-ratio test vs. multinomial model $\chi2=79.58$, $p=0.028$); however, modeling as partial proportional odds resulted in a nominal difference in coefficient estimates across the outcome. Ordinal model is presented for ease of interpretation. Model of partial proportional odds is given in the appendix for comparison.
3. An explained variance greater than unexplained variance overall, based on omnibus F-test p-value < 0.05, Model 1 was more informative (more explained variance), the difference in BIC $\chi2=102.45$(Model2-1)
4. Intercepts indicate cut points (sometimes considered thresholds) and are not directly used in model interpretation
5. High CSW education is defined as some high school education or greater
6. Other health services encompass any involvement in community health programs, often health promotion activities and vaccination campaigns
7. CSW incentive satisfaction and high supervision burden was dichotomized as Yes = "Strongly Agree" or "Agree" and No = Neutral, Disagree, and Strongly Disagree responses
8. Lack of trust was based on a Likert response indicated "disagree" or "strongly disagree" that the community trusts them, or indicated community trust as a top three challenge in performing CEBS duties
9. Supervisor validation is the first factor of the EFA
10. High frequency indicates the CSW responded that supervision by the health facility occurred "Often" rather than "Sometimes' or "Rarely"

11. These variables correspond to other performance metrics and are not included in the modeling

Determinants of Number of Information Sources

Figure 4-1 illustrates slight differences in the type of sources favored by each gender, though there is little difference in the overall number of sources as seen in Table 4-2**.**

Figure 4-1. Type of community rumor source by CSW Gender



**All categories are mutually exclusive; other people in the community refer to word-of-mouth

Supervisor validation made it more likely to have more information sources (OR: 3.209, p<0.001) (Table 4-6). CSWs who were satisfied with their incentive were nearly twice as likely to have more information sources (OR: 1.677, p<0.001) The impact of CSW age, education level, and past involvement in health interventions varied based on the number of information sources. A ten-year increase in age resulted in slight increases in the number of information sources, significant at 3 or more (OR: 1.674, p=0.003) compared to only one source. CSWs with a high school or greater level of education were significantly less likely to have 4 (OR:0.371, p=0.002) or 5 or more sources of information (OR:0.368, p=0.002). CSWs who worked on past health interventions in their community or health facility were more than twice as likely to have 4 (OR: 2.163, p=0.070) or 5 or more information sources (OR: 2.246, p=0.015).

Table 4-6. Determinants of the number of reported rumor sources

A. Unadjusted Bivariate Results

	Two sources			Three sources			Four Sources			Five or more sources		
Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept	-0.108	(-0.36 , 0.14)	0.403	-0.425	(-0.70 , **-0.15**)	**0.003**	-0.932	(-1.26 , **-0.60**)	**<0.001**	-0.784	(-1.09 , **-0.47**)	**<0.001**
County												
County	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Bong	0.523	(0.35 , 0.79)	**0.009**	0.884	(0.61 , 1.29)	0.589	0.754	(0.48 , 1.17)	0.291	0.891	(0.52 , 1.53)	0.728
Grand Cape Mount	0.965	(0.61 , 1.52)	0.899	0.962	(0.65 , 1.43)	0.871	1.073	(0.69 , 1.67)	0.795	0.859	(0.48 , 1.54)	0.668
Lofa	1.097	(0.70 , 1.73)	0.738	1.372	(0.91 , 2.07)	0.205	0.789	(0.48 , 1.29)	0.430	0.798	(0.42 , 1.51)	0.558
CSW Age (10 year increment)	1.193	(1.01 , 1.41)	**0.085**	1.161	(1.00 , 1.35)	0.108	1.353	(1.14 , 1.61)	**0.004**	1.233	(0.99 , 1.54)	0.123
High CSW Education[5]	1.065	(0.74 , 1.54)	0.776	0.956	(0.68 , 1.34)	0.825	0.698	(0.48 , 1.02)	0.118	0.490	(0.31 , 0.78)	**0.012**
CSW has other income	1.681	(1.17 , 2.42)	**0.019**	1.091	(0.77 , 1.54)	0.676	1.381	(0.92 , 2.07)	0.191	2.498	(1.37 , 4.55)	**0.012**
CSW provides other health services[6]	0.693	(0.49 , 0.98)	**0.086**	1.159	(0.84 , 1.61)	0.455	1.587	(1.10 , 2.30)	**0.040**	1.526	(0.95 , 2.44)	0.139
CSW has a phone	1.328	(0.92 , 1.91)	0.201	1.254	(0.89 , 1.77)	0.276	1.871	(1.23 , 2.85)	**0.014**	2.612	(1.43 , 4.75)	**0.008**
CSW adequately compensated[7]	1.942	(1.36 , 2.78)	**0.002**	1.804	(1.29 , 2.53)	**0.004**	2.024	(1.34 , 3.05)	**0.005**	2.858	(1.60 , 5.09)	**0.003**
Walking time >1 hour to HF	1.066	(0.74 , 1.54)	0.774	0.835	(0.60 , 1.17)	0.378	1.155	(0.78 , 1.71)	0.546	1.274	(0.77 , 2.12)	0.432
Trust between CSW/Community[8]	1.211	(0.76 , 1.92)	0.494	1.252	(0.83 , 1.88)	0.366	1.585	(1.02 , 2.47)	**0.088**	1.035	(0.57 , 1.87)	0.925
CSW is validated by supervisor[9]	3.836	(2.65 , 5.55)	**<0.001**	3.166	(2.25 , 4.45)	**<0.001**	3.011	(2.00 , 4.53)	**<0.001**	3.455	(1.97 , 6.05)	**<0.001**
HF has a CSW registry	1.091	(0.47 , 2.52)	0.864	1.912	(0.79 , 4.64)	0.229	1.446	(0.48 , 4.34)	0.580	1.084	(0.32 , 3.68)	0.914
HF displays graphs of disease trends	1.101	(0.78 , 1.56)	0.651	1.233	(0.89 , 1.70)	0.285	0.934	(0.64 , 1.36)	0.764	0.884	(0.55 , 1.42)	0.667
Daily/weekly supervisor communication	1.457	(0.99 , 2.15)	0.111	1.147	(0.80 , 1.65)	0.537	1.037	(0.68 , 1.58)	0.887	1.307	(0.74 , 2.30)	0.435
OIC is burdened by supervision[6]	0.684	(0.45 , 1.04)	0.132	0.756	(0.49 , 1.16)	0.284	0.864	(0.51 , 1.45)	0.642	0.940	(0.44 , 2.00)	0.891
At least one reported case[11]	1.316	(0.92 , 1.88)	0.206	1.056	(0.76 , 1.46)	0.781	0.858	(0.59 , 1.25)	0.499	0.986	(0.62 , 1.58)	0.962
Number of recalled process steps[11]	1.410	(1.17 , 1.69)	**0.002**	1.688	(1.42 , 2.01)	**<0.001**	1.485	(1.22 , 1.81)	**0.001**	1.573	(1.20 , 2.05)	**0.005**
Number of recalled triggers[11]	1.753	(1.41 , 2.18)	**<0.001**	1.726	(1.42 , 2.10)	**<0.001**	2.405	(1.92 , 3.01)	**<0.001**	3.973	(2.95 , 5.35)	**<0.001**

B. Model A: Health Facility and Community Variables[2,3]

	Two sources			Three sources			Four Sources			Five or more sources		
Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept	0.317	(0.10 , 1.01)	0.103	0.085	(0.03 , 0.27)	**<0.001**	0.013	(0.00 , **0.04**)	**<0.001**	0.006	(0.00 , **0.03**)	**<0.001**
County												
Bong	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Grand Cape Mount	0.498	(0.32 , 0.78)	**0.011**	0.931	(0.61 , 1.41)	0.778	0.798	(0.50 , 1.28)	0.432	1.092	(0.60 , 1.98)	0.807
Lofa	0.890	(0.59 , 1.34)	0.642	0.890	(0.59 , 1.34)	0.642	0.890	(0.59 , 1.34)	0.642	0.890	(0.59 , 1.34)	0.642
Female CSW	1.294	(0.84 , 2.00)	0.330	1.379	(0.85 , 2.24)	0.276	1.176	(0.66 , 2.08)	0.637	1.190	(0.67 , 2.11)	0.617
CSW Age (10 year increment)	1.180	(0.97 , 1.43)	0.159	1.261	(1.05 , 1.51)	**0.034**	1.674	(1.36 , 2.06)	**<0.001**	1.282	(0.98 , 1.68)	0.133
High CSW Education[5]	1.257	(0.83 , 1.90)	0.363	0.803	(0.55 , 1.18)	0.349	0.460	(0.30 , 0.71)	**0.003**	0.371	(0.22 , 0.63)	**0.002**
CSW has other income	1.437	(0.96 , 2.15)	0.140	0.951	(0.65 , 1.39)	0.828	0.931	(0.59 , 1.46)	0.794	1.971	(1.04 , 3.75)	**0.083**
CSW provides other health services[6]	0.873	(0.59 , 1.29)	0.567	1.367	(0.95 , 1.97)	0.160	2.163	(1.42 , 3.30)	**0.003**	2.246	(1.30 , 3.88)	**0.015**
CSW has a phone	1.224	(0.82 , 1.83)	0.410	1.182	(0.79 , 1.77)	0.498	1.786	(1.06 , 3.02)	**0.070**	2.284	(0.99 , 5.26)	0.103
CSW adequately compensated[7]	1.677	(1.21 , 2.32)	**0.009**	1.677	(1.21 , 2.32)	**0.009**	1.677	(1.21 , 2.32)	**0.009**	1.677	(1.21 , 2.32)	**0.009**
Walking time >1 hour to HF	1.082	(0.77 , 1.53)	0.707	1.082	(0.77 , 1.53)	0.707	1.082	(0.77 , 1.53)	0.707	1.082	(0.77 , 1.53)	0.707
Trust between CSW/Community[8]	1.190	(0.81 , 1.76)	0.463	1.190	(0.81 , 1.76)	0.463	1.190	(0.81 , 1.76)	0.463	1.190	(0.81 , 1.76)	0.463
CSW is validated by supervisor[9]	3.209	(2.33 , 4.41)	**<0.001**	3.209	(2.33 , 4.41)	**<0.001**	3.209	(2.33 , 4.41)	**<0.001**	3.209	(2.33 , 4.41)	**<0.001**
HF has a CSW registry	1.025	(0.47 , 2.24)	0.959	1.025	(0.47 , 2.24)	0.959	1.025	(0.47 , 2.24)	0.959	1.025	(0.47 , 2.24)	0.959
HF displays graphs of disease trends	1.334	(0.96 , 1.85)	0.148	1.334	(0.96 , 1.85)	0.148	1.334	(0.96 , 1.85)	0.148	1.334	(0.96 , 1.85)	0.148
Daily/weekly supervisor communication	1.388	(0.94 , 2.06)	0.169	1.388	(0.94 , 2.06)	0.169	1.388	(0.94 , 2.06)	0.169	1.388	(0.94 , 2.06)	0.169
OIC is burdened by supervision[6]	0.671	(0.42 , 1.08)	0.170	0.671	(0.42 , 1.08)	0.170	0.671	(0.42 , 1.08)	0.170	0.671	(0.42 , 1.08)	0.170

C. Model B: Community variables only[3]

Variables[1]	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value	OR	90% CI	p-value
Intercept	0.435	(0.18 , 1.05)	0.120	0.112	(0.05 , 0.27)	**<0.001**	0.026	(0.01 , 0.09)	**<0.001**	0.013	(0.00 , 0.05)	**<0.001**
County												
Bong	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-	(ref)	- -	-
Grand Cape Mount	0.599	(0.39 , 0.91)	**0.046**	1.142	(0.77 , 1.70)	0.583	0.967	(0.62 , 1.52)	0.903	1.346	(0.76 , 2.39)	0.393
Lofa	1.128	(0.77 , 1.65)	0.603	1.128	(0.77 , 1.65)	0.603	1.128	(0.77 , 1.65)	0.603	1.128	(0.77 , 1.65)	0.603
Female CSW	1.295	(0.87 , 1.93)	0.289	1.295	(0.87 , 1.93)	0.289	1.295	(0.87 , 1.93)	0.289	1.295	(0.87 , 1.93)	0.289
CSW Age (10 year increment)	1.168	(0.97 , 1.41)	0.171	1.200	(1.01 , 1.42)	**0.075**	1.416	(1.05 , 1.92)	**0.061**	1.233	(0.98 , 1.55)	0.135
High CSW Education[5]	1.268	(0.84 , 1.91)	0.338	0.823	(0.56 , 1.20)	0.399	0.532	(0.35 , 0.81)	**0.014**	0.409	(0.25 , 0.67)	**0.003**
CSW has other income	1.288	(0.87 , 1.90)	0.282	1.103	(0.73 , 1.67)	0.694	1.106	(0.72 , 1.71)	0.701	1.506	(0.75 , 3.04)	0.331
CSW provides other health services[6]	0.847	(0.58 , 1.24)	0.477	1.355	(0.94 , 1.95)	0.169	1.924	(1.27 , 2.93)	**0.010**	2.047	(1.18 , 3.55)	**0.032**
CSW has a phone	1.269	(0.87 , 1.86)	0.304	1.237	(0.83 , 1.84)	0.378	1.575	(0.94 , 2.63)	0.145	1.820	(0.79 , 4.21)	0.233
CSW adequately compensated[7]	1.707	(1.24 , 2.35)	**0.006**	1.707	(1.24 , 2.35)	**0.006**	1.707	(1.24 , 2.35)	**0.006**	1.707	(1.24 , 2.35)	**0.006**
Walking time >1 hour to HF	1.012	(0.72 , 1.42)	0.954	1.012	(0.72 , 1.42)	0.954	1.012	(0.72 , 1.42)	0.954	1.012	(0.72 , 1.42)	0.954
Trust between CSW/Community[8]	1.175	(0.80 , 1.73)	0.492	1.175	(0.80 , 1.73)	0.492	1.175	(0.80 , 1.73)	0.492	1.175	(0.80 , 1.73)	0.492
CSW is validated by supervisor[9]	3.046	(2.22 , 4.17)	**<0.001**	3.046	(2.22 , 4.17)	**<0.001**	3.046	(2.22 , 4.17)	**<0.001**	3.046	(2.22 , 4.17)	**<0.001**

Outcome variable is the reported number of sources used in information gathering, categorized as, 1, 2, 3, 4, and 5 or more.

1. All data are unweighted and based on CSW and health facility clinician self-reports. See "Yes" responses from Table 4-2 for reference categories

2. Proportional odds assumption violated (Likelihood-ratio test vs multinomial model $\chi2=174.92$, $p=0.006$); modelling as partial proportional odds resulted in a noteworthy difference in coefficient estimates across the outcome

3. An explained variance greater than unexplained variance overall, based on omnibus F-test p-value < 0.05, Model 1 was more informative (more explained variance), the difference in BIC $\chi2=59.12$(Model2-1)

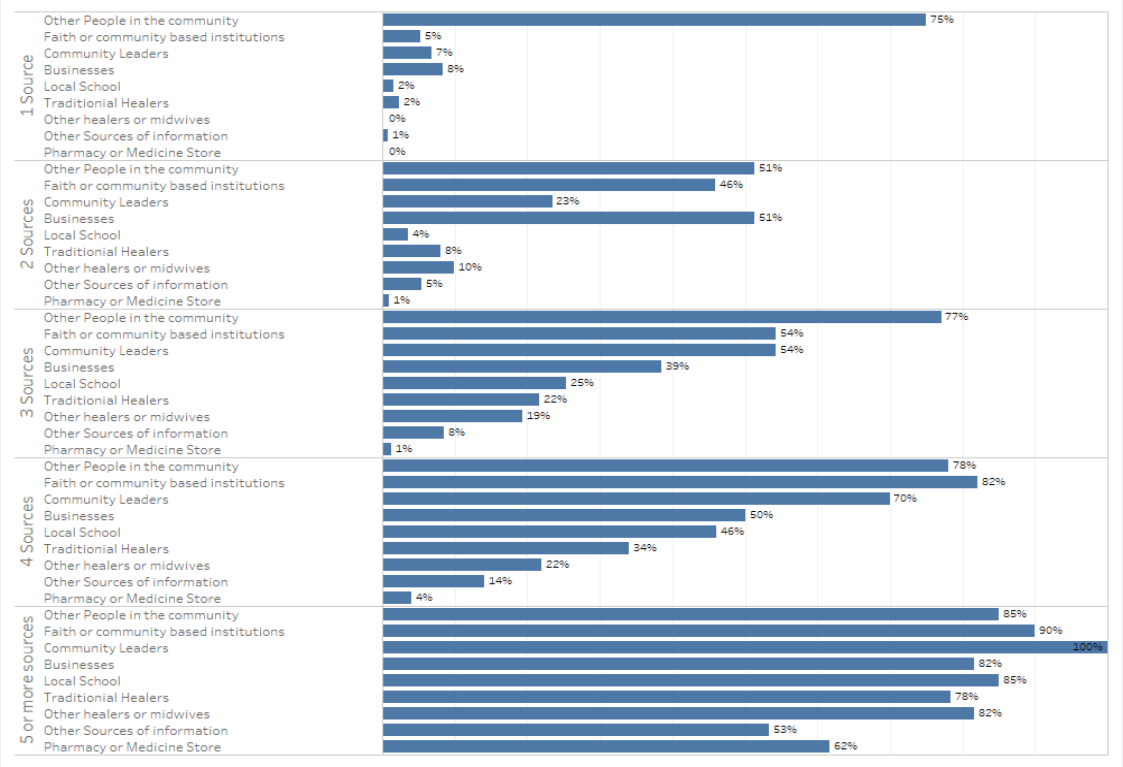
4. Intercepts indicate cut points (sometimes considered thresholds) and are not directly used in model interpretation

5. High CSW education is defined as some high school education or greater
6. Other health services encompass any involvement in community health programs, often health promotion activities and vaccination campaigns
7. CSW incentive satisfaction and high supervision burden was dichotomized as Yes = "Strongly Agree" or "Agree" and No = Neutral, Disagree, and Strongly Disagree responses
8, Lack of trust was based on a Likert response indicated "disagree" or "strongly disagree" that the community trusts them, or indicated community trust as a top three challenge in performing CEBS duties
9. Supervisor validation is the first factor of the EFA
10. High frequency indicates the CSW responded that supervision by the health facility occurred "Often" rather than "Sometimes' or "Rarely"
11. These variables correspond to other performance metrics, and are not included in modelling

The most common source of information was rumors from others in the community,

following by faith based institutions, businesses, and community leaders (Figure 4-2).

Figure 4-2. Type of community rumor source by number of total sources



**All categories are mutually exclusive; other people in the community refer to word-of-mouth

4.5 DISCUSSION

In this analysis, we explored the impact of contextual and input factors across a range of CSW performance metrics for a CEBS program in Liberia. Utilized in the appropriate circumstance, reporting of syndromes from the community increases the sensitivity of disease surveillance and conveys secondary advantages. These programs demand substantial investments. Improving CSW performance provides an opportunity to maximize program efficiency without compromising program activities.

Contrary to the proposed framework (Figure 1-1), we found no correlation between the primary outcome of reporting and process indicators of performance. We had hypothesized that process indicators reflect the quality of active case finding in the community and would, in turn, increase the rates of reporting. This conflicting result suggests CSWs who demonstrate strong performance in reporting without corresponding performance in the process may have missed, or misreported, cases in the community. Communities with active reporting may have under-represented segments of the population, unreported conditions, or inadequate follow-up or verification of suspect triggers. In these cases, trigger reporting alone may not be a reliable or valid indicator of high sensitivity, and both outcome and process indicators should be used in concert during the monitoring and evaluation of the program. This result may also be an artifact of our focus on any reports, rather than the magnitude of report – improved quality metrics may increase the overall number of reports. A focus on determinants of

reporting is a valid approach for conditions such as Guinea-worm disease which identify endemics at village and not individual level.

Substantial county variation was observed for reporting and trigger recall indicators. This was particularly true for reporting outcomes: CSWs in Grand Cape Mount and Lofa had substantially lower odds of ever reporting than CSWs in Bong, accounting for all other determinants. We do not know which unobserved determinants account for this variation. A possible explanation could be localized epidemics or different underlying endemic risks between counties. For instance, in 2016 Bong reported a higher than the usual number of diarrhea cases. Our assumption of at least one report per community during the program period may not be robust. More likely, underreporting rates vary by county based on unobserved health system factors including variable health information system infrastructure. Grand Cape Mount, in particular, had chronic underreporting for all administrative data, evidenced when comparing population-based measles cases in the 2013 Demographic Health Survey to HMIS reports in the same period.[175] Health information reforms which increase demand and use of CEBS data at all levels may improve overall data quality.

4.5.1 Determinants of CSW Performance in Liberia

Incentives and CSW Performance

The lack of correlation between satisfaction with the $30 monthly incentive and reporting was an unexpected finding. During program design, the discussion around incentives centered solely on its expected effect on reporting rates. It is not clear if this adverse finding suggests reporting is more sensitive to structural rather than behavioral

factors. The relationship between incentives and reporting may be confounded by altruism.[21] Deci et al. (1999) propose incentives may crowd out intrinsic altruistic values - creating an inverse relationship.[176] Liberia is a unique setting in this respect. Vigilance in Liberia is high following the 2014-2016 Ebola epidemic, likely driving altruistic behavior to report disease and prevent further morbidity. As new triggers are added and memories of the epidemic fade, this effect may dissipate. Deci et al. (1999) suggest maintaining altruistic values by 1) minimizing authoritative style in disbursing incentives 2) acknowledging excellent performance but not using incentives to strengthen behavior 3) providing a choice on completing tasks and 4) emphasizing the exciting and challenging aspects of the work.[176]

Incentive satisfaction was associated with increases across all three process indicators of performance. It is notable that the altruistic behavior hypothesized to modify reporting outcomes does not appear to have the same effect on these metrics. This disparity may be partially explained by CSWs connecting reporting as the main direct benefit to their community. Further, performance in the process indicators requires a more considerable effort than reporting in many instances. Reporting is a comparably lower burden and can be completed by sending documentation to the patient to the health facility. This finding also suggests that volunteerism may be a satisfactory approach to implementing CEBS programs in non-emergency situations. This is particularly appropriate when disease reporting is prioritized over immediate public health response. Assuming performance in process indicators positively influences active case finding, programs aiming to curb the spread of epidemic-prone and high case

fatality conditions should consider incentivizing workers to reduce false negatives further.

Recognition, Validation, and CSW Performance.

Social validation was assessed through two determinants; trust by the community and recognition by supervisors. The two are complementary; positive relationships with the community increased reporting and recall of process steps, positive relationships with supervisors increased odds of trigger recall and the higher numbers of information sources. We hypothesize a shared mechanism of action. Validation and trust estimate socialization and prestige, which engenders in the CSW a sense of accountability and drives performance.[169] We must also observe the reverse conclusion in this cross-sectional assessment: good performance may lead to cordial relations. Both mechanisms likely are true to some degree, and we are not able to verify any causal pathways in this study. Nevertheless, discussing performance as a downstream result of social validation allows for preparation through program design, and is supported by the literature.[101,177]

Status within the community was anecdotally the main motivation for CSW participation in CEBS, consistent with prior findings.[153] This status is dependent on community trust in the health system, and building trust is a gradual process. Benefits and risks should be clearly communicated during community entry. The design and implementation of CEBS programs should be undertaken with the support and involvement of each community. In Liberia, CSWs were nominated by community health committees and selected by health facilities and NGOs with the goal of recruiting individuals with implicit community support. Community trust in the CSW can also mirror

trust in the larger health system. Association with the health system can be detrimental towards community relationships if service delivery is substandard.[20] Patients are unlikely to inform CSWs of illness if they expect the health facility will not have medicine or the ability to provide treatment. The influence of supervisor validation is more straightforward. Following protocol in Liberia, supervisor meetings should review daily CSW activities, particularly efforts involved in active case finding. It follows that CSW performance in process indicators increase when the relationship is viewed positively. Investing in building social validation can result in ancillary benefits not assessed in this study. Kosfeld and Neckermann (2011) posit social and monetary incentives are mutually reinforcing. The optimal approach is a purposeful combination of both.[168,178]

Supervision and CSW Performance

The goal of supervision and mentorship is to increase performance through iterative improvement. Consistent with previous work, we found no correlation between supervision frequency and performance in any of the four indicators.[153] Despite this, supervision provides secondary benefits, such as acting as a pathway for providing essential supplies and logistics.[179] However, there is potential to overburden already constrained health facility staff with supervisory responsibilities. This should be considered when setting supervision frequency. Likely, clinicians are less familiar with the goals of surveillance activities compared to treatment-focused case management activities. Clinicians in Liberia are provided an incentive to work in rural areas and may not be familiar with the traditions of local tribes. These clinicians may find it challenging

to mentor CSWs in context-specific activities such as building trust, identifying community rumor sources, or convincing a patient to travel to the health facility.

In these settings, supplementing health facility supervision with a diversity of approaches (i.e., self-assessment, peer assessment) may be useful.[180] One solution is to have a CSW report to community leaders or health committees, who are better suited to provide mentorship in these areas. Another approach is to set regular meetings at the health facility attended by all CSWs in the area. This has an added advantage of allowing peers to exchange ideas, benchmark performance, and feel part of a larger effort.[101]

Walking Time and CSW Performance

A walking time of more than one hour between the community and health facility resulted in a substantial reduction in odds of reporting. The impact of walking time varies by setting. In Liberia, walking time is associated with distance, poor infrastructure, and various socioeconomic factors. Lack of transportation was consistently cited as a major barrier in completing activities. CEBS shifts the travel burden from the health facility to the community, resulting in barriers for both patients and CSWs. Documentation sent with referred community members comprises most of the reports. When patients are too sick to travel, the CSW will act as an escort. However, procuring transportation is often prohibitively expensive.

The implications of this finding are alarming: CEBS was not effective at increasing reporting in areas far from the health system where increased sensitivity is most needed. Programs operating in hard to reach areas must take deliberate steps to mitigate the effects of structural barriers to reporting. Investments in health extension workers can

shift the transportation burden and increase the frequency of field visits. Travel reimbursements decrease the monetary burden for community members. Providing resources for communications can help alert the health facility to possible cases. Though logistics are costly, these are worthwhile investments to remove structural barriers to improve reporting performance among CSWs.

Interestingly, owning a phone did not improve the odds of reporting. Availability of a network connection and funds to make phone calls were not considered and may play a role in this adverse finding. Phone ownership may also be associated with unobserved effects such as status within the community or relative wealth. Phone ownership did increase the odds of trigger recall, and the number of information sources used in the community. The decreased odds of recalling process steps is likely tied to ease of reporting – CSWs are more likely to recall the "reporting" step, and neglect follow-up and verification. This result suggests that phone ownership is not enough to increase reporting in Liberia. A mHealth intervention, such as an electronic IDSR (eIDSR) program, may improve reporting by designing around these infrastructure barriers.

Individual Characteristics and CSW Performance

Older CSWs had higher odds of additional sources of information, potentially due to more extensive and established social networks in this group. Further, elders in the community may be community leaders with access to a variety of information sources through their position. On average, CSWs had about three sources of information: 1) community members 2) faith-based or community organizations and 3) community leaders. Older individuals were more likely also to gather information from businesses,

and traditional healers, and midwives. CEBS programs with similar community structures as Liberia can take advantage of this by preferentially recruiting older CSWs, or by designing community entry protocols to ensure CSWs are integrated with elders in the community.

Education at a high school level or greater was negatively associated with having more than three sources of information. This link has been observed in previous research on CHW performance, concluding education leads to overqualification and less investment in the work.[181] Bhattacharji et al. (1986) found a similar effect in a broad-based CSW program in India, suggesting educated workers were less willing and able to engage with households with lower socioeconomic status, though the effect was overcome with supervision.[160] The actual effect of educational level on performance will be highly dependent on context. In Liberia, the high level of unemployment regardless of education status may confound the true magnitude of the association. There may be value in exploring the benefit of setting both minimum and maximum criteria for education during CSW recruitment.

Participation in previous health interventions increased odds for trigger recall and the number of information sources. Most of this experience derived from vaccination campaigns and the Ebola epidemic, though some areas have had community programming provided by international organizations. CSWs with experience in delivering health services are likely to be a known health resource in the community and gained familiarity with health facility staff. Surprisingly, prior experience increases odds of trigger recall, but not the knowledge of the program protocol. On average, CSWs with

prior experience recalled reporting and referral steps at a much higher rate than verification or follow-up. It is possible that prior programs did not incorporate these types of activities and reporting and referral were heavily emphasized during multiple trainings. These findings suggest that programs can gain performance benefits by giving recruitment preference to individuals with prior experience or building surveillance tasks into existing CHW programs.

We found marginal differences between genders; female CSWs had approximately 50% better odds of recalling triggers and process steps. The Liberia CEBS programs focus on highly visible events which will likely be known by many in the community. This characteristic may mask potential individual demographic differences in case finding ability. The effect of gender in CEBS programs is likely grounded in the interaction between the epidemiology of reportable conditions and social norms and constructs. In Liberia, for example, we hypothesize women have an advantage in identifying measles triggers as they were more likely to utilize local schools and word-of-mouth rumor sources, and directly observe cases develop due to their role in child care.

The above findings support recommendations made by Rowe et al. (2005) suggesting performance can be improved by a detailed selection process.[142] However, the above associations are likely specific to the Liberian CEBS program. Kok et. Al (2015) emphasize that individual characteristics have a mixed influence on performance and should be taken into account on a case-by-case basis.[182] Recruitment should also consider ancillary benefits. For instance, our finding that genders have differences in rumor sources suggests a program which strives to achive gender parity in recruitment

will diversify information sorces, anday result in increased knowledge-sharing between CSW peers.[20]

4.5.2 Limitations and Future Work

Liberia's CEBS program was in response to the 2014 West African EVD outbreak, a large-scale event and significant shock to the health system. Galvanized communities likely resulted in performance increases in reporting and detection across all counties. This may have overemphasized estimates for structural barriers over behavioral factors for reporting outcomes. There were limitations in the assessment of some factors. The relationship between CSW demographic profile and performance may be mediated by the client community. The small sample for this study prevented the analysis of these intersectionality effects. Analysis of supervision effects did not include consideration of supervision quality. High-quality supervision is expected to increase the work performance and alter estimates for supervision frequency and supervisor validation.[180]

We tested a subset of the conceptual framework which varied across communities and health facilities. Further assessment of determinants will require comparison across countries and programs. Generalization of these results to other contexts depends on the consideration of both local context and program goals. Despite these limitations, this study quantifies and provides insight into CSW performance in CEBS in Liberia. We also suggest mechanisms which inform the contexts in which they may be relevant.

4.6 CONCLUSIONS & CHAPTER SUMMARY

In this study, we explored the influence of determinants of performance in a pilot CEBS program in Liberia implemented in response to the 2014-2016 West-African Ebola

epidemic. We identified areas which are influence performance in Liberia and may be important for other similar settings as well. High performance of CSWs alone does will not create an effective CEBS program, it must be coupled with informed design choices which promote sustainability and maximize sensitivity and PPV as discussed in Paper 2. As indicated in paper 1, during the epidemic, it proved difficult for the health system to reach the community, and there was a large amount of distrust. An effective CEBS program can build trust, and provides a pathway to increase community participation in disease surveillance and response.

In Liberia, CSWs were at peak performance when they had the trust of the community, positive relationships with their supervisors, were satisfied with their incentives, were within an hour's walking time of the facility, and had prior experience in delivering programs. We also identified a division between reporting and the program activities leading up to reporting.

No factor significantly increased performance across all four indicators. County variation for reporting was also significant, indicating the considerable effect of unobserved variables. We recommend a more rigorous assessment of health system effects on community surveillance which encompass a variety of settings and program design. This will be useful when comparing professional cadres of CSWs and programs which utilize volunteer or informal participants. These findings provide direction for maintaining high levels of CSW performance and sustainable community surveillance programs in Liberia. Though community disease surveillance programs vary in structure

between settings, these data may be useful for similar programs in other low-income countries.

5 Conclusion

Emerging infectious diseases continue to pose a significant threat to global health.[83,109] Low-income countries are especially vulnerable. Development brings new risk factors for emerging disease: shifting migration patterns, new human-animal interfaces, and anthropogenic climate change. Under-resourced disease surveillance systems limit the ability to detect EIDs. The lack preventative vaccines and pharmaceutical interventions further burden the disease surveillance system by imposing complicated case management and disease control interventions. Using surveillance data and results from a community surveillance pilot, this dissertation explores the epidemiological phenomena of the 2014-2016 EVD outbreak in Liberia and explores the potential of community surveillance to add capacity to the disease surveillance system.

5.1 Summary of Findings

In Paper 1, we estimate the EVD outbreak in Liberia resulted in 10,280 cases and 5,121 deaths. The basic reproduction number was estimated to be 1.78, on the lower end of the range of previous *Ebola Zaire* epidemics.[72,183] we estimate the attack rate to be 5.3 per 1,000 persons in exposed communities, and the case fatality rate to be 48.4%, and illustrate substantial variation in all measures over space and time. Coverage of contact tracing, dead body management, and ETU treatment increased over time. Effectiveness of these interventions are less clear. Contact tracing was initiated for only 8.6% of cases, and most of the ETUs treatment beds were built late in the epidemic, and many were never used. There is also evidence that the surveillance system struggled to identify cases in a timely manner; nearly one in three cases were identified after death. The time trends

in transmission and interventions suggest that a reorganization in leadership and community engagement strategy was a turning point in bringing the epidemic under control.

Papers 2 and 3 explore the potential for a community surveillance program to address shortcomings in disease surveillance systems by increasing coverage and engaging communities. We found that over the 29 weeks, the CEBS pilot in the eight bordering counties identified resulted in 3,369 reports which met community trigger definitions, 885 of which met the case definition for the epidemic-prone disease. While we were not able to externally benchmark sensitivity, CEBS reports accounted for at least 31.5% of reports in the national disease surveillance system from these countries during the program. CSWs performed best when reporting diseases which were common, but the reporting of rarer conditions suffered. We identified 4 main archetypes for community surveillance programs; awareness programs are low capacity and typically intended to passively increase linkage to care for risk-prone diseases, community driven programs depend on informal cadres of volunteers trained as key informants, routine programs employ a more formal cadre of CSWs who are able to systematically report and respond to more complicated triggers, and active response programs include active case finding, response activities, and near real-time reporting. Designed as an active response, and transitioned to a routine program, we concluded if the pilot was scaled as initially designed, Liberia would not be able to sustain CEBS programs, primarily due to lack of political and domestic or long term external financial support. A transition to a

community-driven or routine program integrated into existing community health initiatives was proposed as a pathway to scale.

In paper 3, we further investigated CSW performance within CEBS programs. CEBS programs present unique challenges for CSW performance, including the identification of complex disease syndromes, a high burden of reporting, and the ability to affect behavior change and gather diverse sources of information. We also observed that remoteness continues to be a challenge for community reporting in Liberia. CSWs who were within an hour's walk from the health facility had three times the odds of reporting a trigger during the program period compared to those who were more than an hour away. Odds of trigger recall, having more information sources and remembering program protocol were greatest among CSWs who were satisfied with their incentive and had a positive relationship with their supervisor. Personal characteristics also played a role; older CSWs had more sources of information in the community, whereas CSWs with a higher education had fewer sources of information. Female CSWs had higher odds of recalling the reporting process and were able to recall more triggers and had slightly different types of information sources than their male counterparts. The lack of common drivers between reporting and the quality indicators suggest that the quantity of reporting and quality of reporting have unique drivers.

5.2 Implications for Liberia's IDSR Program

The EVD outbreak makes clear the potential for community programs in Liberia to increase the adoption of control measures and increase timeliness of reporting and improve overall resilience to a future emerging disease. However, the country must

garner political support, and identify a program structure which will be financially sustainable. Any attempt at systematizing CEBS in Liberia must also directly tackle transportation barriers, maintain a health supervisory relationship between health facilities and CSWs, and identify a motivating mix of monetary and non-monetary incentives.

The Liberia Ministry of Health and Incident Management System is aware of these concerns. Results from the CEBS evaluation contained in papers 2 and 3 were presented to the Incident Management system in February 2017. CEBS was fully integrated into ongoing plans for recruitment of a formal CSW cadre in rural areas and became the first of eight core modules in a broader care package. In urban areas, a community-driven approach which recruited informal cadre of community volunteers was selected, whereas rural areas maintained a routine approach. The community disease triggers were standardized across the country and published in the National Technical Guidelines for Community Event-Based Surveillance, the Integrated Disease Surveillance and Response Guidelines, and the Community Health Strategy, and all training materials. During the 2017 Research Agenda formulation, community health was at the forefront. NGOs and the Ministry of Health committed to develop a community health information system to further monitor performance of frontline health workers and programs, and research projects pursuing the effectiveness of community engagement strategies and effectiveness of community health structures.

While the integration of CEBS into the broader community health strategy was a welcome first step, there is an ongoing concern about the sustainability of a formalized

CSW program. This new initiative is a relaunch; the last CHW program provided surveillance activities but collapsed in 2012 after many months of missed payments and poor management. The current project is taking a more conservative approach, with recruitment and tools phased over a seven-year period and funded by a World Bank grant. But it is unclear how the country will afford a $70 monthly incentive without support from donors and aid organizations. Further, integration of CEBS into the broader package of services brings substantial savings but also dilutes the recall of rare disease conditions with the daily activities in the larger package of services. Routine simulations, quality training, and proactive monitoring and evaluation can aid in detecting performance issues which do arise. We also suggest an annual calculation of sensitivity and specificity for triggers which have external data sources, such as the upcoming demographic and health survey. These results can be used to fine-tune community trigger definitions to minimize false negatives and respond to changes in clinical presentation.

5.3 Implications for Community Surveillance Programs in LICs

The application of these findings to community surveillance programs in other settings depends on the similarity in context and program goals.[182] Liberia's program is focused on detecting epidemic-prone disease. The reporting burden for CSWs in Liberia is expected to be substantially lower than CSWs in programs which focus on common conditions. This increases the danger of false negatives in Liberia's program, which puts a stronger emphasis on process and quality metrics than may be necessary in other settings.

In Liberia's CEBS approach, CSWs are legally volunteers and receive an incentive, with no salary or ancillary benefits. CSWs are required to fill out paper reports, and thus must be literate at the 6th-grade level and are integrated into a formal line of supervision and reporting. Other settings will have different structures and goals, resulting in different recruitment strategies and definition of metrics. Programs with fewer triggers and a less formal structure may not focus on the same quality metrics. Programs in areas with better infrastructure may not face the same barriers in transportation and reporting.

Liberia is also unique in circumstance. CEBS was piloted in the wake of the EVD epidemic, and the benefit of disease surveillance to the community was known. Many CSWs reported they would continue to work without monetary incentive, as the service provided to the community and stature afforded were motivating factors themselves. As the memory of the epidemic wanes, or in settings without a recent health shock, motivations to participate and extent of general community involvement will differ.

With these caveats in mind, inferences from this body of work can be applied to low-income countries, humanitarian and public health crises, or other settings with under-resourced disease surveillance systems. There is a clear potential of community surveillance programs to improve sensitivity of disease surveillance and community relations and multiply the effectiveness of traditional disease control measures to reduce morbidity and mortality. To be sustainable, program design should align with sensitivity goals and organizational and financial resources, as defined by our CEBS typology.

Community driven programs which recruit key informants should maximize the variability in recruitment by age, gender, and education to take advantage of the

different types and number of information sources in the community. If multiple key informants are not possible, older, lower education level community members would maximize the overall number of information sources. Another option would be to target recruitment (especially if the disease target is more prevalent in a certain demographic) to take advantage of certain venues, such as recruiting school teachers or traditional healers. A mapping of markets, businesses, and vectors can aid in identifying potential resources and risks. Community driven programs can also incorporate community-led supervision to increase performance without establishing expensive formal supervision structures.

Routine programs which require frequent reporting should minimize structural barriers, especially in communities' distance from health facilities. This can include transportation vouchers at the health facility, transportation allowance, or a mHealth intervention which allows for reporting by phone from the field, where network infrastructure exists. In addition to the recommendations above, active programs should provide incentives to CSWs to maximize the quality of reporting.

5.4 Next Steps

This work identified several areas for further research to better understand the theory behind community surveillance sustainability and performance. To improve implementation, we must better understand how case finding occurs in the community, and how the complexity of trigger definitions affects rates of false negatives. This is especially important for passive programs which do not have a defined case finding process. Our finding that unknown disease and death triggers were often not recalled by

CSWs suggests more work needs to be done to improve the performance of programs with a central goal of detecting emerging infectious disease. Since community surveillance relies on timely reporting, further investigation on the types of transportation barriers and effectiveness of potential solutions may yield insights on how to increase the overall rate of reporting.

A more in-depth investigation on the differences between the proposed CEBS typology can further inform policy options. There are many program design options and blending of program types is common. The effect of some policy options (such as the size of the catchment area, effectiveness of non-monetary incentives, single vs multiple triggers) could not be explored in this work; and may have major impacts on sustainability and case finding. As the pilot evaluated in this study was implemented vertically, the effect and considerations when surveillance activities are integrated into a larger package of services is not clear. Our findings when looking across recall of triggers suggest surveillance activities may be a secondary priority to services which conducted more routine, but further research should be done to measure this effect. We also did not explore how CEBS data could be used other than for starting case investigations. Programs should explore how the information is fed back to the community, which may improve overall engagement and establish a line of accountability back to the community. In this work, we describe community trust as a necessary pre-requisite, but it is possible community surveillance activities can be leveraged to reduce stigma and increase trust in the health system. Given the barriers in disease control community distrust created in both this outbreak, and the ongoing EVD outbreak in the Congo,

community surveillance programs may be able to play a important role in turning the tide of community.

Preventing widespread outbreaks due to emerging infectious disease will require community cooperation and engagement. Community surveillance programs provide a structured method to quickly identify disease and an avenue for health communication from within the community. Though these programs are an asset, their limited implementation and integration into large scale programs can be traced to the difficulty to sustain and scale such programs, especially in low-income countries with low health care accessibility, where this benefit would be most felt. The results presented in this dissertation attempt to clarify the role of community surveillance programs and identify the levers which can be controlled to improve sustainability and performance of these programs, so they may be an asset in future outbreaks.

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7 Appendices

7.1 PAPER 1 SUPPLEMENT

7.1.1 Supplemental figure and tables

Table 7-1. Key Pairs for Deterministic Matching

Key #	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	Variable 7
1	County of Residence	Case ID from DHIS					
2	County of Residence	Case ID from Survivor Database					
3	County of Residence	Case ID from VHF Database					
4	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Has a source listed	Quarter of Onset Date	Patient Sex	
5	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Missing Age	Patient Sex	Rare First/Last Name Pair	
6	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Missing Age	Patient Sex	Same week of onset	
7	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Age	Patient Sex	Quarter of Onset Date	
8	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Age (Decade)	Has a source listed		
9	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Age (Ones digit)	Village of Residence	Quarter of Onset Date	
10	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Quarter of Death Date	Patient Sex	Village of Death	
11	County of Residence	First and Last Name	Less than 3 occurences of full name in combined dataset	Rare First/Last Name Pair	Patient Sex	Patient Age	
12	First and Last Name	First and Last Name	Less than 3 occurences of full name in combined dataset	Rare First/Last Name Pair	Patient Sex	Quarter of Onset Date	
13	County of Residence	Less than 3 occurences of full name in combined dataset	Rare First/Last Name Pair	Patient Sex	Same week of onset		
14	County of Residence	First and Last Name	Missing Age	Patient Sex	Missing Age	Same week of onset	
15	County of Residence	First and Last Name	Missing Age	Patient Sex	Same week of onset		
16	County of Residence	First and Last Name	Patient Age	Date of Report			
17	County of Residence	First and Last Name	Patient Age	Date of Symptom Onset			
18	County of Residence	First and Last Name	Patient Age	Date of Symptom Onset (Month/day transposed)			
19	County of Residence	First and Last Name	Patient Age (Decade)	Date of Death			
20	County of Residence	First and Last Name	Patient Age (Decade)	Date of Report			
21	ID of Source Case	First and Last Name	Patient Age (Decade)	Same week of onset	Village of Death		
22	County of Residence	Is a source record	Reversed First and Last Name	Patient Age (Decade)	Patient Age (Decade)	Patient Sex	Quarter of Death Date
23	County of Residence	Reversed First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Age (Decade)	Quarter of Onset Date	Municipality	
24	County of Residence	Reversed First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Age_remainder	Quarter of Onset Date	Village of Residence	
25	Reversed First and Last Name	Less than 3 occurences of full name in combined dataset	Patient Sex	Quarter of Onset Date	Village of Residence	Patient Sex	

Table 7-2. Selected Epidemiological Parameter Estimates of for Previous Zaire Ebolavirus, from Kerkhove et. al.[72]

Parameter	**Estimate**
Incubation Period Distribution (range of central estimates, (range)) *	5.3–12.7 (1–21) days
Serial interval Distribution (range of mean estimates)	10–16.1 days
Khan et al. (mean)[184]	14 days‡
Muyembe & Kipasa (approximation)[185]	10 days ‡
Dowell et al. (median, (range))[186]	Med=17 days (9–25)
White & Pagano (mean, (IQR))[187]	5.82 days (5.43–7.60)
Maganga et al. (median, (range), mean, s.d.)[188]	Med=16 days (3–27), 16.1 days, 4.4
R $_0$ **(range of estimates)**	1.36–4.71

Chowell et al. (estimate, s.d.)[8]	1.83, 0.06
Ferrari et al. (estimate, (95% CI)[189]	3.65 (3.05, 4.33)
Legrand et al. (estimate, (95% CI))[75]	2.7 (1.9, 2.8)
Lekone & Finkenstädt (estimate, s.d.)[190]	1.36, 0.13
Ndanguza et al. (estimate, (95% CI))	2.22 (1.90, 2.73)
White & Pagano (estimate, (IQR))[187]	1.93 (1.74–2.78)
Camacho et al. (estimate, (95% CI))[191]	4.71 (3.92, 5.66)
R_t (range of estimates)	0.84-1.29
Maganga et l. (estimate, (95% CI)[188]	1.29 (-4.72-7.29) 0.84 (-0.38,2.06)
Symptom onset to hospitalization	4–5; Med=3–4
Khan et al. (mean, median, (range), n[184]	5, Med=4 (0–19), *n*=219
Rowe et al. (mean, s.d., median, (range))[192]	4, 3.3, Med=3 (0–14)
Camacho et al. (median, (95% CI)) [191]	Med=3.00 (2.81, 3.20)
Symptom onset to death	**6–10.1**
Camacho et al. (median, (95% CI)) [191]	Med=7.49 (7.30, 7.69)
Bwaka et al. (mean, (range), n) 37	10.1 (3–21), *n*=86
Dowell et al. (median)[186]	Med=10
Khan et al. (mean, median, (range), n)[184]	9.6, Med=9 (0–34), *n*=224
Nkoghe et al. (mean, (range), n)[193]	6.2 (3–13), *n*=12 Med=6 (<15 years old) Med=9 (15–29 years old)
Sadek et al. (median, n)[194]	Med=10 (30–44 years old) Med=8 (45–59 years old) Med=9.5 (>59 years old), overall *n*=226
Georges et al. (range)[195]	12–18
Maganga et al. (median, (range), mean, s.d.) [188]	11 (1–30), 11.3, 6.8
Symptom onset to recovery	10
Camacho et al. (median, (95% CI)) [191]	10.00 (9.80, 10.19)
Hospitalization to discharge	17
Khan et al. (mean, median, (range), n)[184]	17, Med=14 (0–56), *n*=34
Hospitalization to death	4.6
Khan et al. (mean, median, (range), n)[184]	4.6, Med=4 (0–20), *n*=185

Figure 7-1. Ebola Epidemiological Curve by County, Liberia, 2015-2016

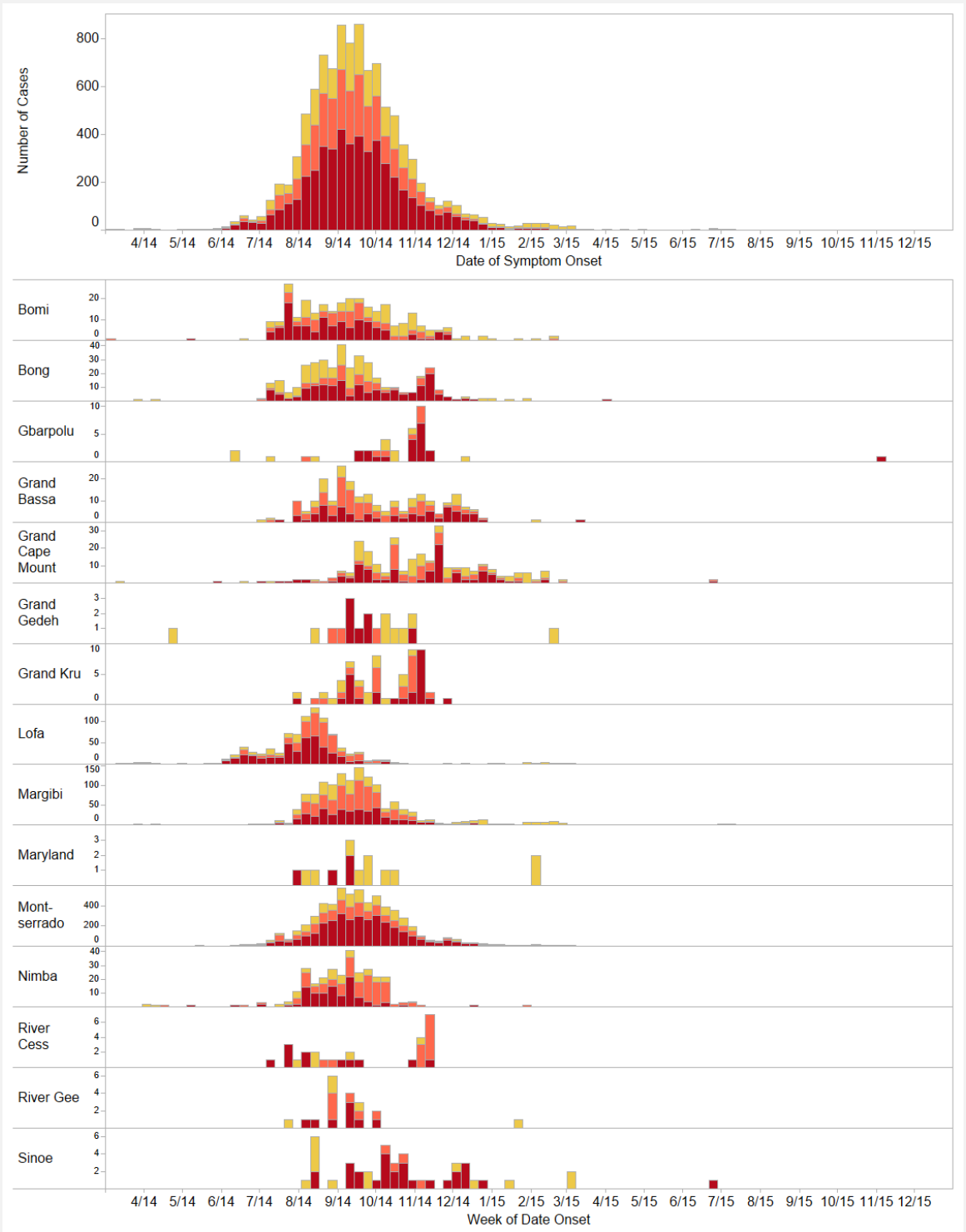


Figure 7-2. Moving Average of Ebolavirus Case Fatality Rate by County

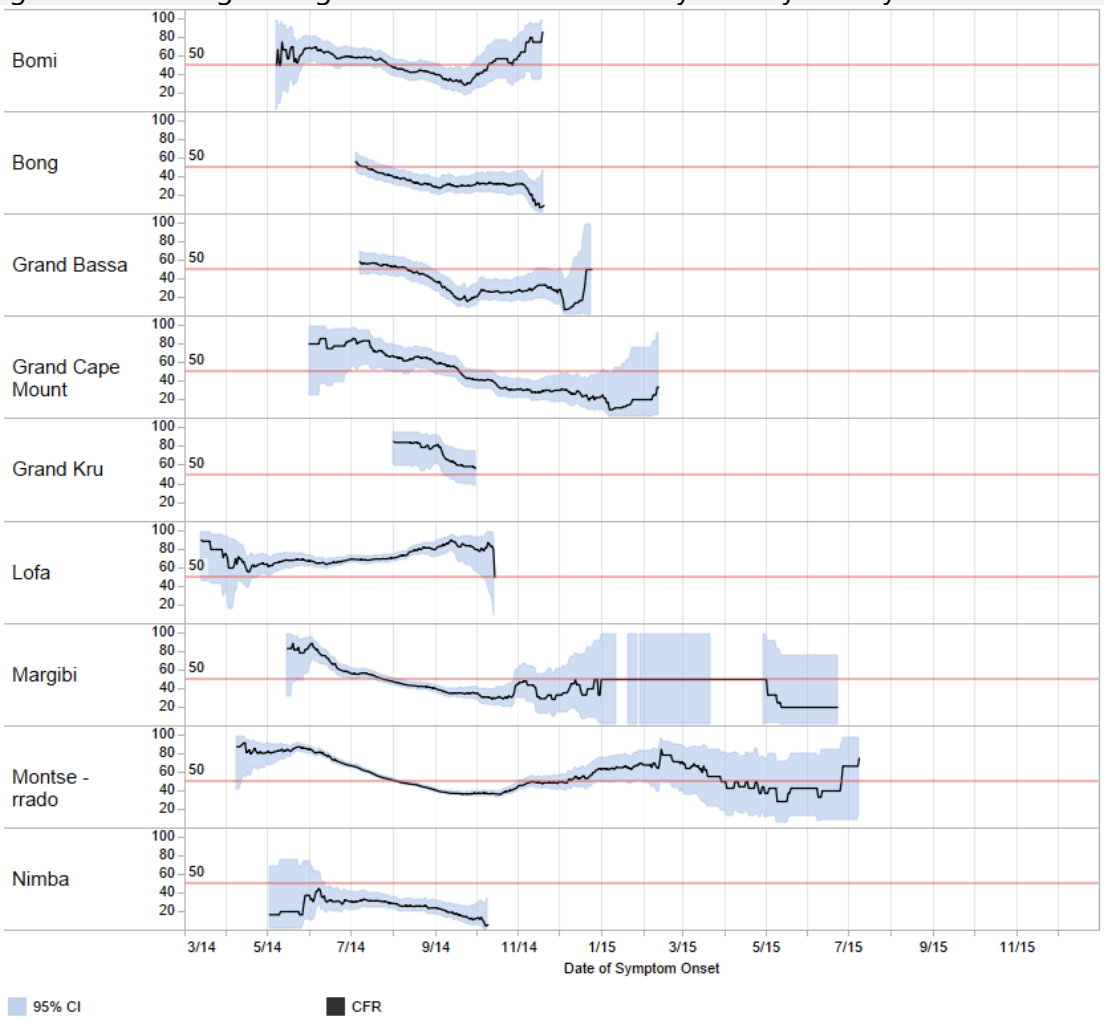


Figure 7-3. Timeliness of Reporting, Liberia, 2015-2016

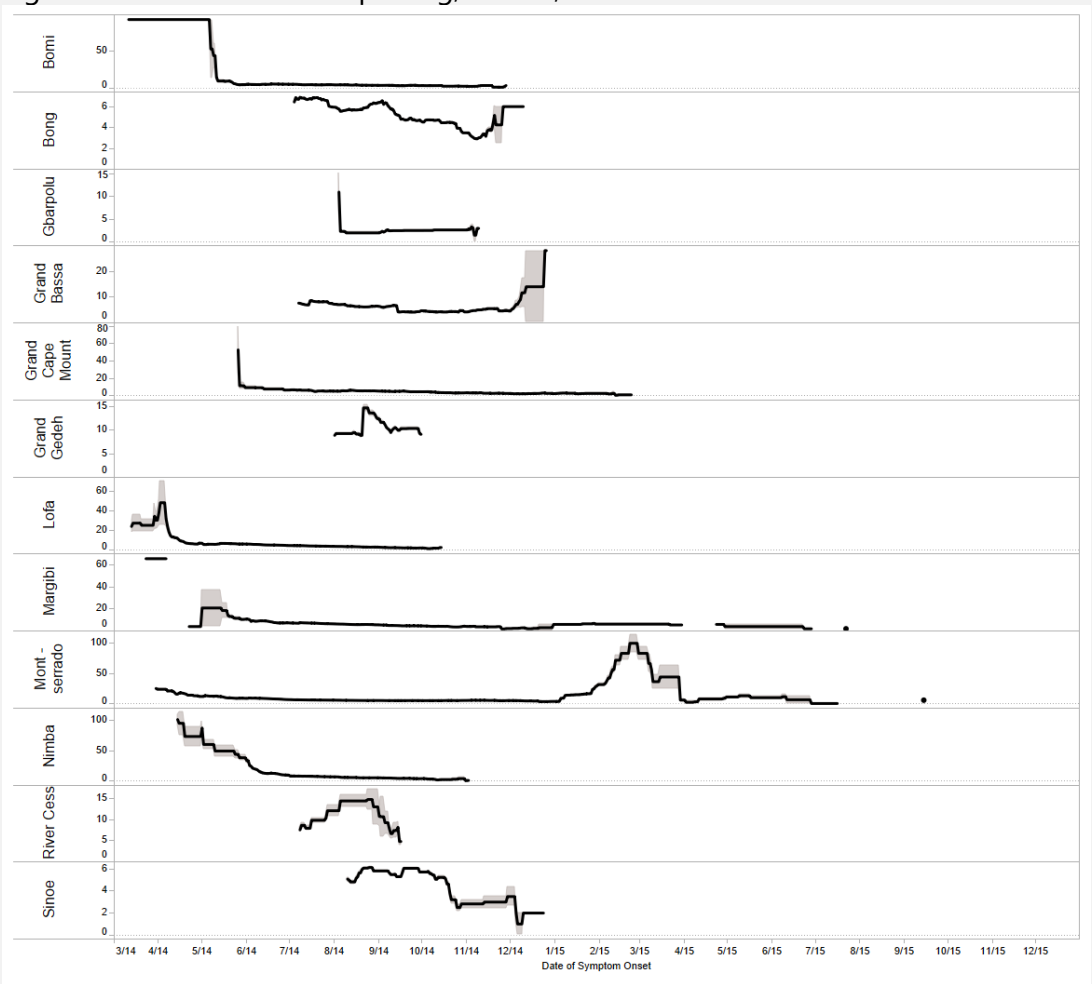


Figure 7-4. Instantaneous Reproductive Number by County, Liberia, 2015-2016

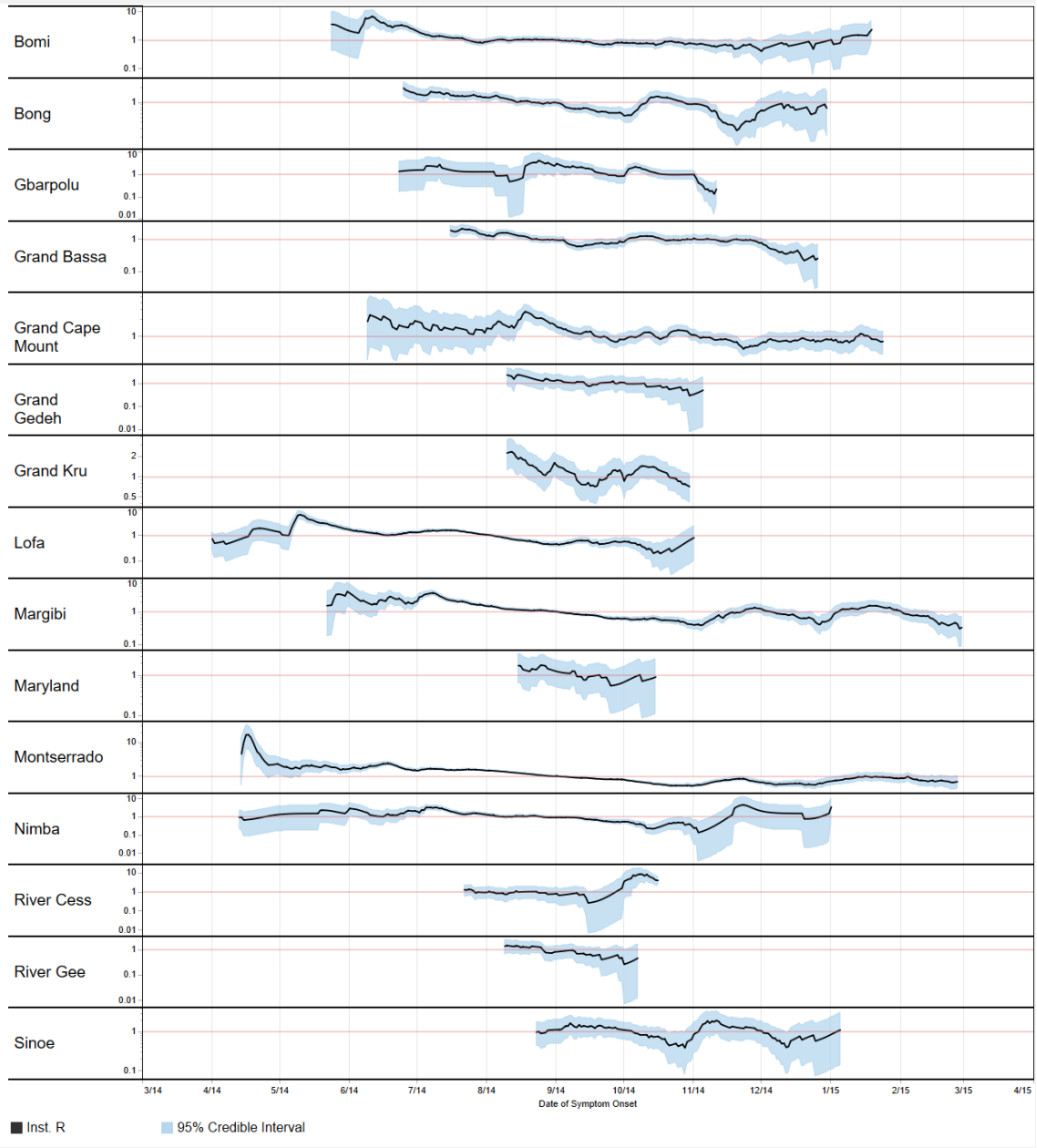


Figure 7-5. Subset of directly observed transmission clusters, Liberia, 2015-2016

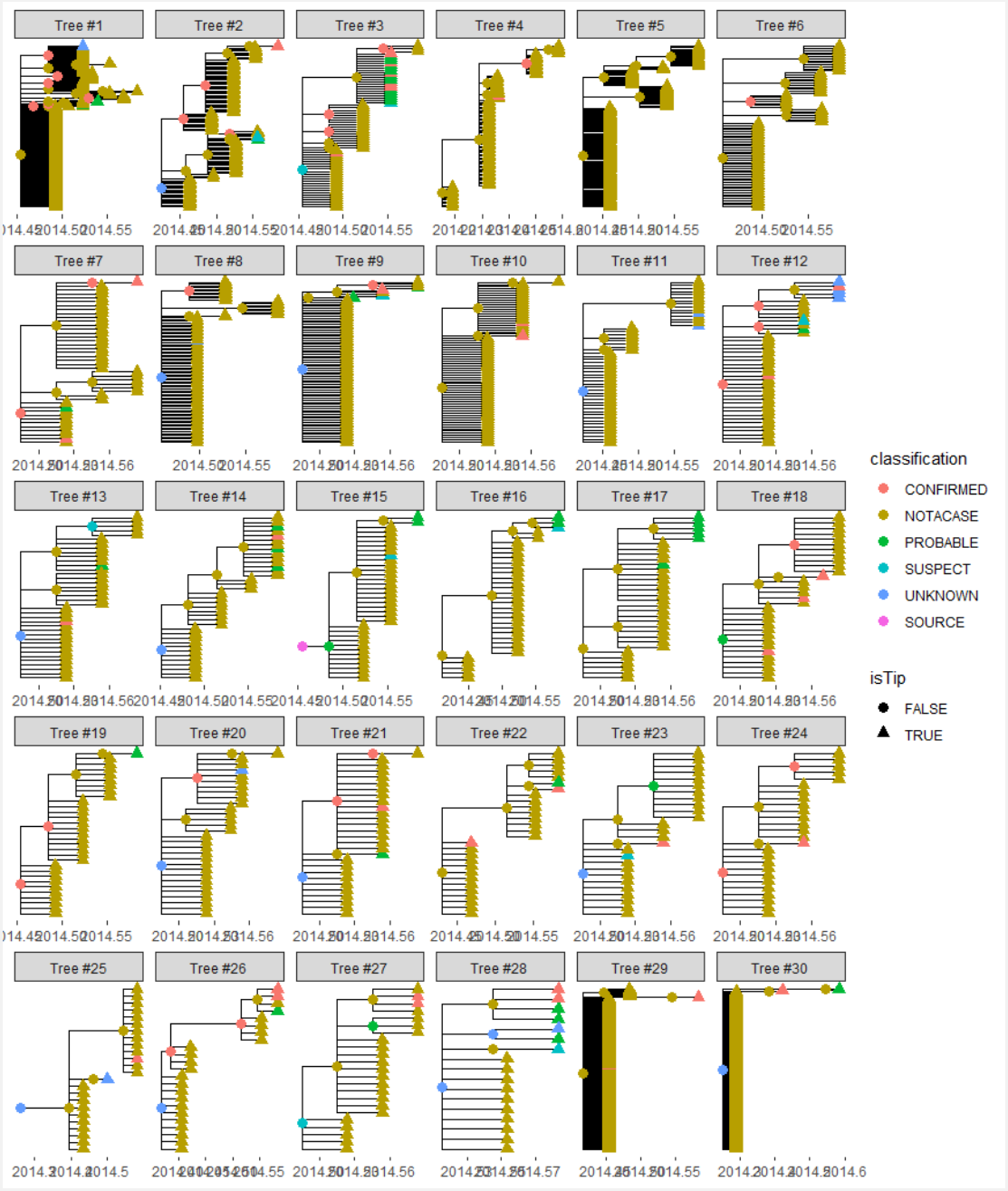


Figure 7-6. Inst. Reproduction number by population density and county

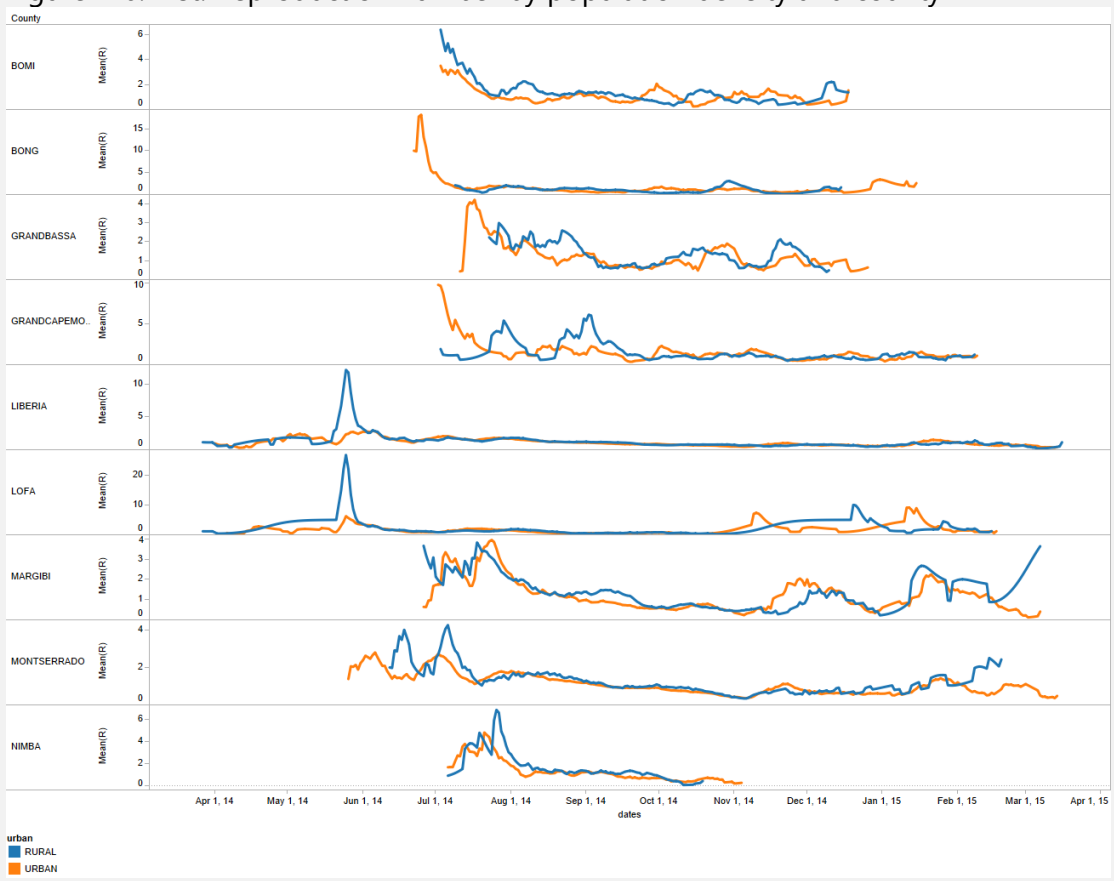
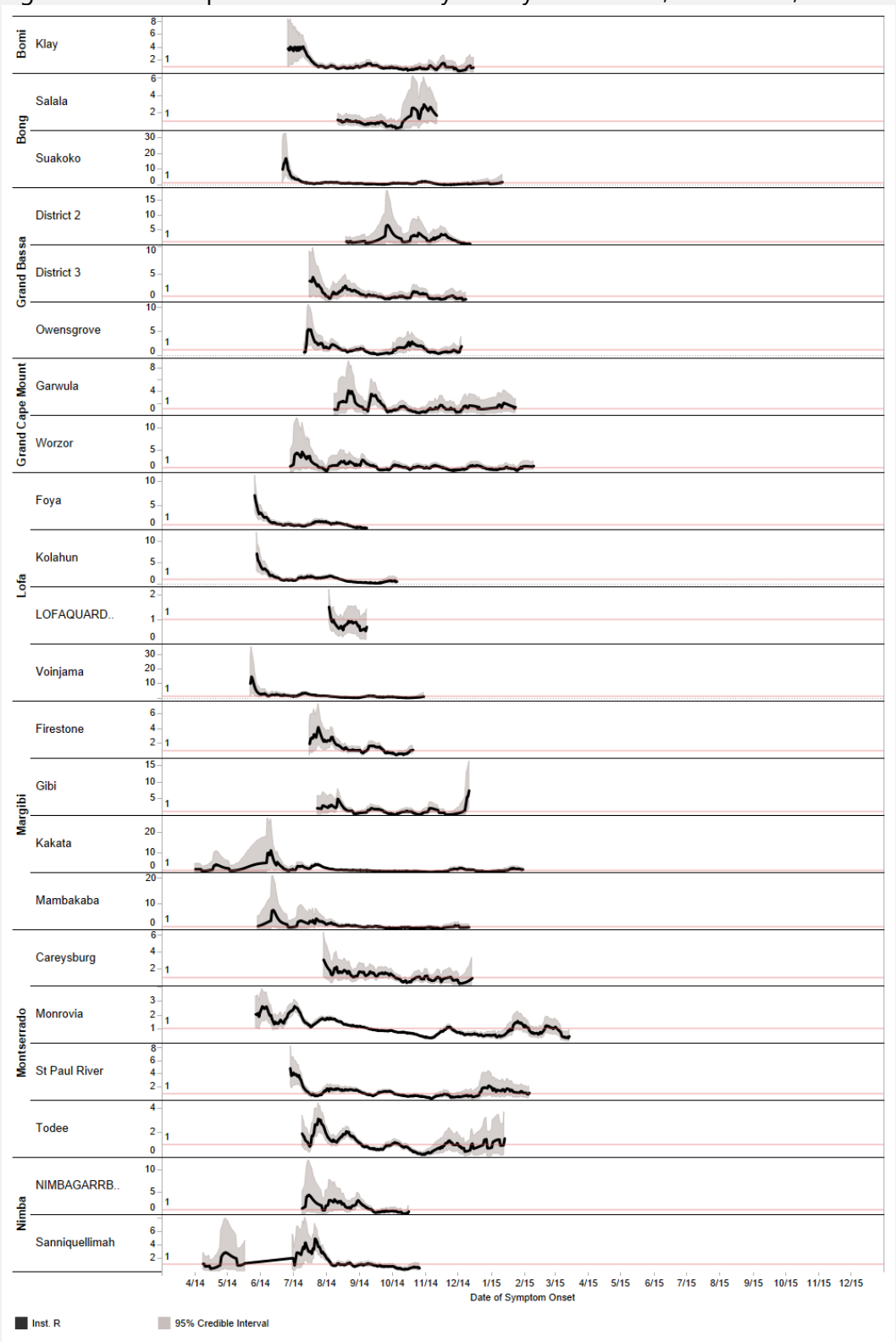


Figure 7-7. Inst. Reproduction number by county and district, 2015-2016, Liberia



7.1.2 Reporting Forms

Figure 7-8. EVD Case Report Form

LIBERIA EBOLA CASE INVESTIGATION FORM

Date of report DD__ MM__ YY__ **County of report**_____
Village of report _____
Investigation initiated by ☐ Case Investigation Team ☐ ETU ☐ CCC ☐ Burial ☐ Other_____

IDSR ID_____-_____-_____
County ID Facility ID Patient ID

REQUIRED FIELDS

Patient's surname_____ **Patient's other names**_____
Age (yrs) ____ (0 if <1 y.o.) **Sex** ☐M ☐F **Date patient first became sick** DD___ MM___ YY___
Healthcare worker / Works in health setting ☐Y ☐N ☐Unk
If yes, Position _____ Healthcare facility_____
Family/friend/immediate contact name _____ **Phone number** _____
Religion ☐ Christian ☐ Muslim ☐ Atheist ☐ Traditionalist ☐ Other ☐ Unk
Where patient lives Village/Town_____ Clan/Zone_____
District_____ County _____ Country_____
Where patient first became sick Village/Town_____ Clan/Zone_____
District_____ County _____ Country_____

Ask the patient about the following symptoms if possible, or else ask a close relative or friend

Fever	☐Yes ☐No ☐Unk	Joint pain	☐Yes ☐No ☐Unk
Vomiting/nausea	☐Yes ☐No ☐Unk	Headache	☐Yes ☐No ☐Unk
Diarrhea	☐Yes ☐No ☐Unk	Cough	☐Yes ☐No ☐Unk
Intense fatigue/weakness	☐Yes ☐No ☐Unk	Difficulty breathing	☐Yes ☐No ☐Unk
Anorexia/loss of appetite	☐Yes ☐No ☐Unk	Difficulty swallowing	☐Yes ☐No ☐Unk
Abdominal pain	☐Yes ☐No ☐Unk	Hiccups	☐Yes ☐No ☐Unk
Chest pain	☐Yes ☐No ☐Unk	Unexplained bleeding	☐Yes ☐No ☐Unk
Muscle pain	☐Yes ☐No ☐Unk	*If yes,* list areas of body	_____

Has the patient previously visited a health care facility for this illness? ☐Yes ☐No ☐Unk
If yes, dates in facility DD___ MM___ YY___ to DD___ MM___ YY___
Facility name _____ County _____
Was the case previously a contact? (i.e. followed by contact tracers) ☐Yes ☐No ☐Unk
Did the patient contact an ill person in the last 21 days before becoming ill? ☐Yes ☐No ☐Unk

Name of source case	Last contact date	County	Village/Town	Status	Date of Death
	/ /			□ Alive □ Dead	/ /
	/ /			□ Alive □ Dead	/ /

Did patient attend a funeral in the last 21 days before becoming ill? ☐Yes ☐No ☐Unk
If yes, Name deceased _____ Funeral date DD___ MM___ YY___ Village _____
County _____Did the patient touch or carry the body? ☐Yes ☐No ☐Unk

Did patient travel outside their home town in the last 21 days before becoming ill? ☐Yes ☐No ☐Unk
If yes, Country of travel ☐Liberia ☐Guinea ☐Sierra Leone ☐Other_____
If Liberia, Village _____County _____ Dates DD___ MM___ YY___ to DD___ MM___ YY___

Patient current status
☐Admitted to ETU ☐Admitted to CCC *If yes* ETU/CCC name_____ on DD__ MM__ YY__
☐Awaiting transportation to ETU or CCC
☐Refused to go to an ETU or CCC because _____
☐Dead *If dead,* **Date of death** DD___ MM___ YY___ ☐Not applicable

Epidemiological case classification ☐Suspected ☐Probable ☐Not a case ☐Unknown

Other comments

Completed By _____ Phone number _____ Position _____
RETURN COMPLETED FORM TO THE COUNTY HEALTH TEAM - Date received DD___ MM___ YY___ V1.5 (6/11/16)

LIBERIA EBOLA CASE INVESTIGATION PACK-AGE

IDSR ID_____-_____-_____
County ID **Facility ID** **Patient ID**

FILL OUT THIS SECTION AND GIVE TO ETU/CCC

Patient's surname _____ **Patient's other names**_____

Age (yrs) ____ (0 if <1y.o.) **Sex** ☐ M ☐ F

Where patient lives Village/Town_____ Clan/Zone_____

District_____ County _____ Country_____

Family/Friend/Immediate contact name_____**Phone number**_____

Investigator name_____ **Investigator phone number**_____

Date outcome information completed DD___ MM___ YY___

Final status of patient ☐Discharged/Recovered ☐ Dead

☐Discharged/Never tested positive ☐Discharged/Triage (no testing)

If patient recovered and discharged

Hospital/Ebola Treatment Unit discharged from _____

County _____ Date of discharge DD___ MM___ YY___

If patient is dead

Date of death DD___ MM___ YY___

Place of death ☐Community location ☐ETU ☐CCC ☐Hospital ☐Specify location name_____

Date of burial DD___ MM___ YY___ Burial conducted by ☐Family/Community ☐Burial Team

Completed By _____ Phone number _____ Affiliation □ CIT □ Burial team □ ETU □ CCC

Form 6/11/2016

Keep this form at location where patient is isolated (e.g. hand to ambulance driver).

Fill out at time of patient's recovery and discharge OR at time of patient's death.

Once patient outcome known, return to County Health Team

Ministry of Health

Integrated Disease Surveillance and Response

Contact Tracing Form

Contact Information:

Contact First Name:_____ Contact Last Name:_____ Circle One: Sex: M F Age:_____ Circle One: Years Months

Contact County:_____ Contact District:_____ Contact Village:_____

Contact Phone #:_____ Locating Information:_____

Contact Head of Household:_____ Contact Type:_____

Source Case Information: Name_____ IDSR-ID:_____
(County-Health Facility-CaseID)

	DAYS OF FOLLOW-UP																													
Contact seen? (mark with 'X' if seen)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SYMPTOMS/SIGNS*. Mark with an 'X' if contact has symptom.																														
Fever																														
Painful muscles or joints																														
Weakness																														
Nausea or Vomiting																														
Diarrhea (non-bloody / bloody)																														
Headache																														
Painful throat or swallowing																														
Red eyes																														
Any bleeding from nose, mouth, ears, or rectum																														
Other 1:																														
Other 2:																														
Other 3:																														
Temperature reading 1:																														
Temperature reading 2:																														

Record symptoms and signs as appropriate for disease of outbreak, specify other when used

If contact developed symptoms: Date of symptom onset:____/____/_____ dd/mm/yy Date of hospitilisation: ____/____/_____ dd/mm/yy

Completed by:_____ Position/Title:_____ Date:_____/_____/_____ (dd/mm/yy)

v2.0 (6/16)

Figure 7-9. Contact Tracing Form

Figure 7-10. Contact Listing Form

Ministry of Health

Integrated Disease Surveillance and Response

Contact Listing Form

Case's IDSR ID: ____-____-____ Case Name: _____ Case's Sex: M F

Case's County: _____ Case's District: _____ Case's Village: _____

Case's Head of Household: _____ Date of symptom onset: ___/___/___ (dd/mm/yy) Date Hospitalization: ___/___/___ (dd/mm/yy)

No.	Surname	First name	Sex (M/F)	Age (yrs)	Phone Number	Head of Household	Village	District	Relationship to Case	Date of Last Contact (dd/mm/yy)	Type of contact* (1, 2, 3, 1st 4th)

*Contacts= **1 -** slept, ate or spent time in the same household or room as case **2 -** Direct physical contact with the case (dead or alive)

3 - has touched or shared linens, clothes or dishes/eating utensilks of the case body fluids (blood, urine, saliva, feces)

4 - has touched his / her body fluids (blood, urine, saliva, feces, semen) **5 -** needs to be followed for other reason, specify (e.g. contact with affected animal)

Completed by (Print Name): _____ Title: _____ Date: _____

Reporting Instructions

Return this completed form to the outbreak investigation team

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7.2 PAPER 2 SUPPLEMENT

7.2.1 Community Event-Based Surveillance Triggers

Acute Flaccid Paralysis (Cripple Sickness)
Any person with weakness in the legs and arms or not able to walk

Measles
Any person with hot skin and spot-spot and/or red eyes

Human Exposure to Rabies
Any person who is bitten by a dog or any other animal

Acute Bloody Diarrhea
Any person passing bloody pu-pu or slimy (slippery pu-pu with stomach pain

Meningitis
Any person with hot skin and stiff neck

Viral Hemorrhagic Fever
Any person who has fever and two and two or more other symptoms (headaches, vomiting, runny stomach, weak in the body, yellow eyes), or who died after serious sickness with fever and bleeding

Acute Watery Diarrhea
Running stomach. Any person passing three or more watery pu-pu within one day

Neonatal Tetanus (jerking sickness)
Baby who is normal at birth, then after two days is not able to suck and starts jerking

Neonatal (young baby) death
Baby who dies at birth or within 28 days after birth

Maternal (Big belly) death
Women who dies with big belly or within 42 days after baby is born or when the belly move

?

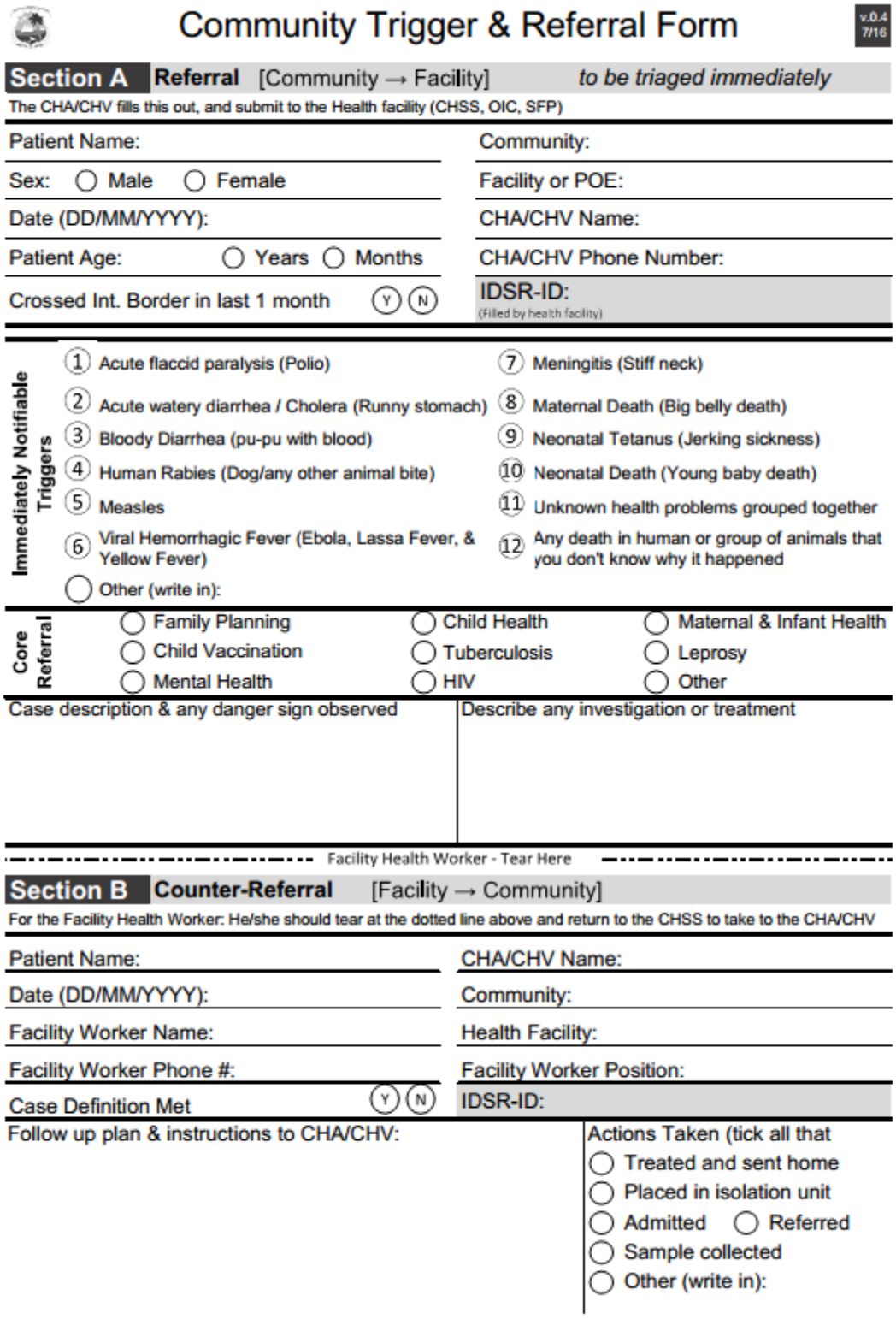
Unexplained cluster of disease
Unknown health problems group together; any health problem that you don't know about that is happening to many many people or animals in the same community

?

Unexplained cluster of death
Any death in human or group of animals that you don't know why it happened

7.2.2 CEBS and IDSR Reporting Forms

Figure 7-11. CEBS Reporting Form



Community Trigger & Referral Form v.0.4 7/16

Section A **Referral** [Community → Facility] *to be triaged immediately*

The CHA/CHV fills this out, and submit to the Health facility (CHSS, OIC, SFP)

Patient Name:	Community:
Sex: ◯ Male ◯ Female	Facility or POE:
Date (DD/MM/YYYY):	CHA/CHV Name:
Patient Age: ◯ Years ◯ Months	CHA/CHV Phone Number:
Crossed Int. Border in last 1 month (Y) (N)	IDSR-ID: (Filled by health facility)

Immediately Notifiable Triggers

1. Acute flaccid paralysis (Polio)
2. Acute watery diarrhea / Cholera (Runny stomach)
3. Bloody Diarrhea (pu-pu with blood)
4. Human Rabies (Dog/any other animal bite)
5. Measles
6. Viral Hemorrhagic Fever (Ebola, Lassa Fever, & Yellow Fever)
7. Meningitis (Stiff neck)
8. Maternal Death (Big belly death)
9. Neonatal Tetanus (Jerking sickness)
10. Neonatal Death (Young baby death)
11. Unknown health problems grouped together
12. Any death in human or group of animals that you don't know why it happened

◯ Other (write in):

Core Referral

◯ Family Planning	◯ Child Health	◯ Maternal & Infant Health
◯ Child Vaccination	◯ Tuberculosis	◯ Leprosy
◯ Mental Health	◯ HIV	◯ Other

Case description & any danger sign observed	Describe any investigation or treatment

Facility Health Worker - Tear Here

Section B **Counter-Referral** [Facility → Community]

For the Facility Health Worker: He/she should tear at the dotted line above and return to the CHSS to take to the CHA/CHV

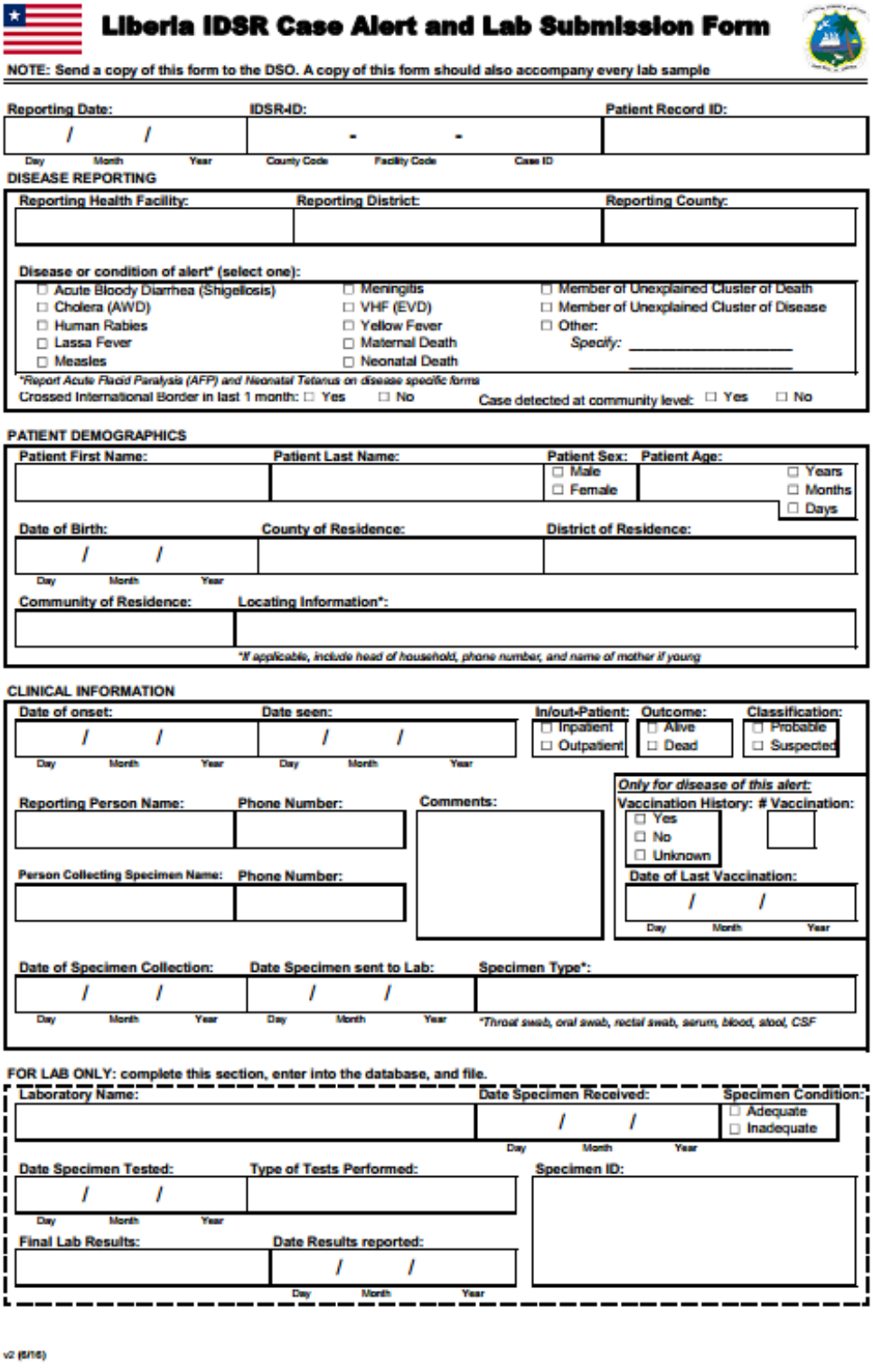
Patient Name:	CHA/CHV Name:
Date (DD/MM/YYYY):	Community:
Facility Worker Name:	Health Facility:
Facility Worker Phone #:	Facility Worker Position:
Case Definition Met (Y) (N)	IDSR-ID:

Follow up plan & instructions to CHA/CHV:

Actions Taken (tick all that

- ◯ Treated and sent home
- ◯ Placed in isolation unit
- ◯ Admitted ◯ Referred
- ◯ Sample collected
- ◯ Other (write in):

Figure 7-12. IDSR Reporting Form



Liberia IDSR Case Alert and Lab Submission Form

NOTE: Send a copy of this form to the DSO. A copy of this form should also accompany every lab sample

Reporting Date: / / (Day / Month / Year)

IDSR-ID: - - (County Code / Facility Code / Case ID)

Patient Record ID:

DISEASE REPORTING

Reporting Health Facility:

Reporting District:

Reporting County:

Disease or condition of alert* (select one):

- ☐ Acute Bloody Diarrhea (Shigellosis)
- ☐ Cholera (AWD)
- ☐ Human Rabies
- ☐ Lassa Fever
- ☐ Measles
- ☐ Meningitis
- ☐ VHF (EVD)
- ☐ Yellow Fever
- ☐ Maternal Death
- ☐ Neonatal Death
- ☐ Member of Unexplained Cluster of Death
- ☐ Member of Unexplained Cluster of Disease
- ☐ Other: Specify: _____

*Report Acute Flaccid Paralysis (AFP) and Neonatal Tetanus on disease specific forms

Crossed International Border in last 1 month: ☐ Yes ☐ No

Case detected at community level: ☐ Yes ☐ No

PATIENT DEMOGRAPHICS

Patient First Name:

Patient Last Name:

Patient Sex: ☐ Male ☐ Female

Patient Age: ☐ Years ☐ Months ☐ Days

Date of Birth: / / (Day / Month / Year)

County of Residence:

District of Residence:

Community of Residence:

Locating Information*:

*If applicable, include head of household, phone number, and name of mother if young

CLINICAL INFORMATION

Date of onset: / / (Day / Month / Year)

Date seen: / / (Day / Month / Year)

In/out-Patient: ☐ Inpatient ☐ Outpatient

Outcome: ☐ Alive ☐ Dead

Classification: ☐ Probable ☐ Suspected

Reporting Person Name:

Phone Number:

Comments:

Person Collecting Specimen Name:

Phone Number:

Only for disease of this alert:

Vaccination History: ☐ Yes ☐ No ☐ Unknown

Vaccination:

Date of Last Vaccination: / / (Day / Month / Year)

Date of Specimen Collection: / / (Day / Month / Year)

Date Specimen sent to Lab: / / (Day / Month / Year)

Specimen Type*:

*Throat swab, oral swab, rectal swab, serum, blood, stool, CSF

FOR LAB ONLY: complete this section, enter into the database, and file.

Laboratory Name:

Date Specimen Received: / / (Day / Month / Year)

Specimen Condition: ☐ Adequate ☐ Inadequate

Date Specimen Tested: / / (Day / Month / Year)

Type of Tests Performed:

Specimen ID:

Final Lab Results:

Date Results reported: / / (Day / Month / Year)

v2 (5/16)

Figure 7-13. Weekly Report Form

MINISTRY OF HEALTH

INTEGRATED DISEASE SURVEILLANCE AND RESPONSE

Weekly Health Facility Data Collection and Reporting Ledger

County:________________ District:________________ Health Facility:________________________ Dates: From ___/___/_____ to ___/___/_____

Disease/Condition	Monday					Tuesday					Wednesday					Thursday					Friday					Saturday					Sunday					Weekly Summary				
	Live		Dead			Live		Dead			Live		Dead			Live		Dead			Live		Dead			Live		Dead			Live		Dead			Live		Dead		
	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*	<5	≥5	<5	≥5	SC*
Acute Flaccid Paralysis																																								
Cholera (Severe AWD)																																								
Diarrhea with blood (Shigella)																																								
Human Rabies																																								
Lassa Fever																																								
Measles																																								
Meningitis																																								
Neonatal Tetanus		X		X			X		X			X		X			X		X			X		X			X		X			X		X			X		X	
Viral Hemorrhagic Fever (inc Ebola)																																								
Yellow Fever																																								
Maternal Death	X	X	X			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X		
Neonatal Death	X	X				X	X				X	X				X	X				X	X				X	X				X	X				X	X			
Unexplained cluster of health events																																								
Unexplained cluster of deaths	X	X				X	X				X	X				X	X				X	X				X	X				X	X				X	X			
Other (write in):																																								
Other (write in):																																								
Total Cases at Facility																																								

*SC: Number of samples collected for disease

Reported by:____________________ Position/title:__________________ Signature:____________________ Date:____________________

Reporting Instructions: Health Facility Level: Send a copy to DSO every Monday by 11:00AM and file a copy

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7.3 PAPER 3 SUPPLEMENT

Table 7-3. Expected number of community reports by county

	HMIS Disease Reports[1]										Population[3]	Rate of HMIS disease reports per 250 (adjusted for 23 weeks)[4]
Counties in Liberia	Acute Flaccid Paralysis	Bloody Diarrhea	Cholera	Lassa Fever	Measles	Meningitis	Neonatal Tetanus	Watery Diarrhea	Yellow Fever	Maternal Death[2]		
Bomi	-	8	-	-	70	2	4	1,105	-	15	110,762	1.80
Bong*	48	8	5	4	137	74	2	5,396	1	27	439,104	2.15
Gbarpolu*	-	53	4	-	6	14	-	832	-	18	109,799	1.40
GrandBassa	-	84	21	6	59	6	-	2,423	-	38	291,910	1.50
GrandCapeMount*[5]	1	16	-	-	11	3	-	371	2	23	167,325	0.42
GrandGedeh*	4	86	3	-	40	1	3	617	14	184	164,931	0.96
GrandKru	-	62	7	-	5	5	-	1,835	2	18	76,256	4.21
Lofa*	3	248	93	-	186	69	-	10,114	120	170	364,554	5.01
Margibi	4	668	19	-	183	37	1	3,258	3	183	276,412	2.61
Maryland*	-	225	18	-	21	9	-	2,915	1	21	178,994	2.97
Montserrado	565	420	49	5	402	53	-	8,632	4	416	1,472,421	1.19
Nimba*	8	83	25	28	524	16	5	12,456	12	258	608,363	3.66
RiverCess	2	18	-	-	4	28	-	807	6	5	94,158	1.53
RiverGee*	-	30	-	-	5	-	2	507	13	14	87,943	1.08
Sinoe	33	104	1	-	31	-	-	2,357	-	5	134,821	3.11
Total	668	2,113	245	43	1,684	317	17	53,625	178	1,395	4,577,753	2.18

Data from national Health Management Information System for subset of diseases which are passively collected from health facilities

7.3.1 *Weighted Regressions*

Table 7-4. Odds of CSW Ever Reporting during program period (23 weeks), adjusted

Variables[1]	OR	p-value	90% CI
County			
Bong	(ref)	-	- -
Grand Cape Mount	0.082	**<0.001**	(0.05 , 0.15)
Lofa	0.305	**<0.001**	(0.18 , 0.52)
Female CSW	0.749	0.415	(0.42 , 1.35)
CSW Age (10 year increment)	1.013	0.926	(0.81 , 1.27)
High CSW Education[5]	0.635	**0.068**	(0.42 , 0.95)
CSW has other income	1.713	**0.037**	(1.12 , 2.61)
CSW provides other health services[6]	1.255	0.397	(0.80 , 1.96)
CSW has a phone	0.961	0.875	(0.63 , 1.47)
CSW adequately compensated[7]	1.393	0.208	(0.90 , 2.15)
Walking time >1 hour to HF	0.252	**<0.001**	(0.15 , 0.43)
Trust between CSW/Community[8]	1.406	0.334	(0.78 , 2.52)
CSW is validated by supervisor[9]	1.013	0.960	(0.66 , 1.56)
HF displays graphs of disease trends	1.071	0.814	(0.66 , 1.73)
Daily/weekly supervisor communication	0.680	0.249	(0.39 , 1.18)
OIC is burdened by supervision[6]	0.865	0.657	(0.50 , 1.49)
Intercept 3[4]	3.742	0.124	(0.91 , 15.36)

Adjusted for survey design effects (multi-level model with finite population correction, and weighted to represent all CSWs in the program)

Table 7-5. Odds of CSW Recalling Triggers, adjusted

Variables[1]	OR	p-value	90% CI
County			
Bong	(ref)	-	- -
Grand Cape Mount	1.139	0.611	(0.75 , 1.74)
Lofa	1.806	**0.025**	(1.17 , 2.78)
Female CSW	1.583	0.145	(0.94 , 2.66)
CSW Age (10 year increment)	1.019	0.871	(0.84 , 1.23)
High CSW Education[5]	1.410	0.133	(0.97 , 2.06)
CSW has other income	1.391	0.127	(0.97 , 1.98)
CSW provides other health services[6]	1.417	0.118	(0.98 , 2.04)
CSW has a phone	1.586	**0.034**	(1.11 , 2.26)
CSW adequately compensated[7]	2.152	**0.001**	(1.50 , 3.08)
Walking time >1 hour to HF	1.096	0.697	(0.74 , 1.62)
Trust between CSW/Community[8]	1.176	0.481	(0.80 , 1.73)
CSW is validated by supervisor[9]	1.936	**0.002**	(1.38 , 2.72)
HF displays graphs of disease trends	0.778	0.265	(0.54 , 1.13)
Daily/weekly supervisor communication	1.014	0.962	(0.62 , 1.66)
OIC is burdened by supervision[6]	1.064	0.854	(0.61 , 1.87)
Intercept 1	0.217554	0.748	(-0.91 , 1.34)
Intercept 2	2.417298	**0.001**	(1.32 , 3.52)
Intercept 3	4.292799	**<0.001**	(3.17 , 5.42)

Adjusted for survey design effects (multi-level model with finite population correction, and weighted to represent all CSWs in the program)

Table 7-6. Odds of CSW Recalling Program Process, adjusted

Variables[1]	OR	p-value	90% CI
County			
Bong	(ref)	-	- -
Grand Cape Mount	0.965	0.878	(0.65 , 1.42)
Lofa	1.304	0.283	(0.87 , 1.96)
Female CSW	1.320	0.282	(0.86 , 2.02)
CSW Age (10 year increment)	1.090	0.437	(0.91 , 1.31)
High CSW Education[5]	0.921	0.676	(0.66 , 1.28)
CSW has other income	0.830	0.424	(0.56 , 1.22)
CSW provides other health services[6]	1.221	0.319	(0.88 , 1.70)
CSW has a phone	0.573	**0.015**	(0.40 , 0.83)
CSW adequately compensated[7]	1.630	**0.024**	(1.14 , 2.32)
Walking time >1 hour to HF	0.860	0.468	(0.61 , 1.21)
Trust between CSW/Community[8]	0.722	0.271	(0.44 , 1.18)
CSW is validated by supervisor[9]	1.368	0.146	(0.96 , 1.95)
HF displays graphs of disease trends	0.828	0.366	(0.59 , 1.17)
Daily/weekly supervisor communication	0.880	0.626	(0.57 , 1.36)
OIC is burdened by supervision[6]	0.964	0.882	(0.64 , 1.45)
Intercept 1	-2.59486	**<0.001**	(-3.76 , -1.43)
Intercept 2	-0.48606	0.470	(-1.60 , 0.63)
Intercept 3	1.21356	**0.072**	(0.11 , 2.32)
Intercept 4	3.497789	**<0.001**	(2.32 , 4.67)

Adjusted for survey design effects (multi-level model with finite population correction, and weighted to represent all CSWs in the program)

Table 7-7. Odds of CSW using more information sources, adjusted

Variables[1]	OR	p-value	90% CI
County			
Bong			
Grand Cape Mount	0.908	0.705	(0.59 , 1.39)
Lofa	0.996	0.986	(0.67 , 1.49)
Female CSW	1.508	0.074	(1.03 , 2.20)
CSW Age (10 year increment)	1.327	0.013	(1.10 , 1.60)
High CSW Education[5]	0.857	0.491	(0.59 , 1.24)
CSW has other income	1.171	0.475	(0.81 , 1.69)
CSW provides other health services[6]	1.272	0.243	(0.90 , 1.79)
CSW has a phone	1.383	0.108	(0.99 , 1.93)
CSW adequately compensated[7]	1.858	0.003	(1.32 , 2.61)
Walking time >1 hour to HF	1.112	0.623	(0.78 , 1.59)
Trust between CSW/Community[8]	0.944	0.807	(0.64 , 1.39)
CSW is validated by supervisor[9]	3.317	<0.001	(2.35 , 4.68)
HF displays graphs of disease trends	1.220	0.354	(0.85 , 1.74)
Daily/weekly supervisor communication	1.200	0.497	(0.77 , 1.87)
OIC is burdened by supervision[6]	0.710	0.224	(0.45 , 1.13)
Intercept 1	1.457834	0.017	(0.47 , 2.45)
Intercept 2	2.724246	<0.001	(1.73 , 3.72)
Intercept 3	3.71051	<0.001	(2.72 , 4.70)
Intercept 4	4.57363	<0.001	(3.58 , 5.57)

Adjusted for survey design effects (multi-level model with finite population correction, and weighted to represent all CSWs in the program)

7.3.2 Survey Tools

HBMM CEBS EVALUATION
COMMUNITY QUESTIONAIRE

Instructions: Use this tool to interview gCHVs about CEBS and POE activities. Ensure the gCHV interviewed is the same as on your listing, as multiple gCHVs may be present in a community. Record answers in the boxes.

Identification		
A0_1	Respondent ID	
A0_2	County Name	
A0_3	District Name	
A0_4	Community Name	

Interview Information			
A0_6	Interviewer Name		
A0_7	Time beginning of interview	|_||_|:|_||_|	
A0_8	Time at end of interview	|_||_|:|_||_|	
A0_9	Result	1. Completed 2. Partly Completed 3. gCHV not present 4. Refused 99. Other	☐
A0_10	Interview Date	__ __ / __ __ / __ __ __ __ M M D D Y Y Y Y	

Supervisor Signature

CONSENT			
PROMPT: Today we will be talking about Community Event Based Surveillance, or "CEBS" as a part of the IDSR strategy to improve disease surveillance in Liberia. As you may know, CEBS is a way to use Community Health Workers and Assistants to refer potential cases of priority disease to the health facility. We have been implementing CEBS in your county, and want to understand how we can make the program sustainable and produce better data. This is an evaluation of the program, not a supervision or performance assessment. Your responses will be kept completely anonymous.			
A0_10	Do you consent to the interview and wish to proceed?	1. Yes 2. No	☐
SECTION 1: BACKGROUND INFORMATION			
A1_1	What are the biggest health problems in your community?	**1)**	
		2)	
		3)	
A1_2	What is your district of residence?		
A1_3	What is the health facility you report to?		
A1_4	What is your current position in the surveillance system?		
A1_5	What is your community of residence?		
A1_6	What is your gender?	1. Male 2. Female 8. No response	☐
A1_7	How old are you?	|___||___| years *(DK = 88)*	
A1_8	What is the last grade you completed in school?	1. No formal schooling 2. Elementary 3. Junior High 4. Senior High 5. College/University 8. Don't Know 9. Other	☐
A1_9	Do you have another source of income?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to A1_10**
A1_9x	If you have another source of income, what is it?		

A1_10	Do you provide any other health services besides CEBS?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to next section**
A1_10x	What other health services do you provide?		

SECTION 2: BEHAVIORAL DETERMINANTS			
A2_1	Have you been trained in CEBS sometime in the past year (since summer 2015)?	1. Yes 2. No 8. Don't Know	☐
A2_2	Can you give me some reasons why your CEBS work is important to the community?	**1)**	
		2)	
		3)	
A2_3	In CEBS we use community triggers, which are symptoms which may indicate a sickness in the community and a need to go to the health facility. Can you please list all the triggers you can remember? *DO NOT READ ANSWERS. Check off the following as the respondent mentions them, and prompt for more.*	*Check off the following as the gCHV mentions them:*	
		Any person with weakness in the legs and arms or not able to walk (polio)	☐
		Running stomach. Any person passing three or more watery pu-pu within one day (acute water diarrhea)	☐
		Diarrhea with blood, Any person passing bloodying pu-pu or slimy pu-pu with stomach pain (acute bloody diarrhea)	☐
		Any person who is bitten by a dog or other animal (rabies)	☐
		Any person with hot skin and spot-spot or red eyes (measles)	☐
		Any person who has fever with two or more of headaches, vomiting, runny stomach, weak in the body, yellow eyes, or died after serious sickness with fever and bleeding (viral hemorrhagic fever)	☐
		Any person with hot skin fever and stiff neck (meningitis)	☐
		Big belly death, woman who dies with big belly or within 42 days after baby is born when belly move (maternal death)	☐

		Jerking sickness. Baby who is normal at birth, then after two days is not able to suck starts jerking (neonatal tetanus)	☐
		Young baby death. Baby who dies at birth or within 28 days after birth (neonatal death)	☐
		Unknown health problems grouped together, that is happening to many many people or animals in the community	☐
		Any death in human or animals that you don't know why it happened	☐
A2_4	Briefly list the steps you take once you hear about a possible trigger:	**1)**	
		2)	
		3)	
		4)	
		5)	

SECTION 3: Technical Determinants			
A3_1	Do you currently have a phone that can text?	1. Yes 2. No 8. Don't Know	☐
A3_2	Which of these networks can you use in your community? *(read the list and mark all that apply)*	1. Cellcom 2. Lonestar 3. LibTelco 4. Novafone 5. No network available 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 9. ☐ **If not 9, skip to A3_3**
A3_2x	What other network do you use?		
A3_3	Do you have access to internet?	1. Yes 2. No 8. Don't Know	☐
A3_4a	In the past month, have you run out of reporting forms?	1. Yes 2. No 8. Don't Know	☐
A3_4b	On average, how long does it take to get more forms after you have run out?	1. Less than a day 2. A few days 3. More than a week 4. Never	☐
A3_5	In the past month, how often did you fill out the CEBS alert form after detecting a trigger?	1. Often (every person) 2. Sometimes (most persons) 3. Rarely (some persons) 4. Never	☐

A3_6	What is a reason you might not give a form to the person?		
A3_7	How long does it take you to get to the nearest health facility by walking?	1. Less than an hour 2. More than an hour	☐
A3_8	How do you get to the nearest health facility?	1. Walking 2. Motorbike 3. Taxi 4. Personal car 9. Other	☐ **If not 9, skip to A3_9**

A3_8x	If another form of transportation is used, which one?		
A3_9	What are the sources of health information in the community? *DO NOT READ ANSWERS. Give examples of types of information: finding out about vaccinations or health alerts. Check all that apply and prompt for more answers*	1. Other people in the community 2. People working with the health system 3. Radio 4. Newspaper 5. Television 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 9. ☐
A3_10	What are the sources of rumors or information about sickness in your community which you use? *DO NOT READ ANSWERS. Check all that apply and prompt by asking CHV to think about who they have received triggers from*	1. Local school 2. Pharmacy or medicine store 3. Other healers or midwives 4. Stores, businesses, and markets 5. Churches, mosques, or community organizations 6. Community leaders 7. Traditional healer 8. Other people in the community 9. Other source of information	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐
A3_10x	What are other sources of information?		

SECTION 4: Organizational Determinants			
A4_1	How often do you talk with the OIC of your health facility about health business in your community?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 6. Don't Know	☐
A4_2	Has the DSO ever come to your community?	1. Yes 2. No 8. Don't Know	☐
A4_3	Have you been involved in any outbreak response activities with the DSO or OIC?	1. Yes 2. No 8. Don't Know	☐
A4_4	Is your community leader involved in your CEBS business?	1. Yes 2. No 8. Don't Know	☐
A4_5	How often do you meet with your field supervisor?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 6. Don't Know	☐
A4_6	How often do you receive feedback from the OIC after referring someone to the health facility?	1. Often (every person) 2. Sometimes (most persons) 3. Rarely (some persons) 4. Never	☐
A4_7a	Is there a Community Health Committee in your community you meet to talk about CEBS business?	1. Yes 2. No 8. Don't Know	☐
A4_7b	What kinds of things do you talk about?		
A4_8	How many households do you cover?	___ ___ households *(DK = 88)*	
A4_9	How often do people with triggers go to the health facility after you ask them to?	1. Often (every person) 2. Sometimes (most persons) 3. Rarely (some persons) 4. Never	☐
A4_10	In the past one month, has there been anyone from your community who does not seek care because of: *(reach each choice and check if yes)*	1. Thought it would go away by itself 2. Transportation is too expensive 3. Too far, no transportation 4. Services too expensive 5. Unfriendly staff 6. Inconvenient hours 7. Religious beliefs 8. No one to accompany me 9. Other (specify)	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 8. ☐ 9. ☐
A4_10x	If other reason someone does not seek care, what is it?		

A4_11	What do you do if the patient is not able or refuses to go to the health facility?		
A4_12	Did you receive any sort of CEBS job aid with pictures which help you do your work?	1. Yes 2. No 8. Don't Know	☐
A4_13	About how many hours a day do you spend doing this job?	___ ___ hours *(<1 hours = 00 hours; DK = 88)*	
A4_14	How many days a month are you away from the community?	___ ___ days *(<1 days = 00 days; DK = 88)*	
A4_15	When you have to leave the community, how do you find out about the health events that happened while you were gone?		
A4_16	Tell me the main challenges of your job for CEBS.	**1)** **2)** **3)**	
A4_17	Do you have suggestions for how CEBS could be improved? *(Prompt for at least two)*	**1)** **2)** **3)**	
A4_18	Do you receive incentive for your work?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to A4_20**
A4_19	How much do you receive a month in USD for CEBS activities?	___ ___ USD *(DK = 88)*	
A4_20	If the government can't pay money what other things would make you satisfied?	**1)** **2)** **3)**	

SECTION 5. Culture of Information

PROMPT: For the last section, I will give you statements. You will tell me to what extent do you agree with the following on a scale?

(read the full scale, and circle the answers)

		1. Strongly Agree	2. Agree	3. Neutral (neither agree or disagree)	4. Disagree	5. Strongly Disagree
A5_1	I feel discouraged when the data that I collect/record is not used for taking action	1	2	3	4	5
A5_2	Collecting data is meaningful/useful for me	1	2	3	4	5
A5_3	I feel that the data I collect is important for the community	1	2	3	4	5
A5_4	I feel that collecting data is a burden, I have better things to do	1	2	3	4	5
A5_5	My work of collecting data is appreciated and valued by my supervisors	1	2	3	4	5
A5_6	I feel adequately compensated for my work	1	2	3	4	5
A5_7	People in the community trust the health facility to provide health services	1	2	3	4	5
A5_8	I feel people trust and talk to me about their health conditions	1	2	3	4	5
A5_9	People sometimes face stigma from the community about health conditions	1	2	3	4	5
A5_10	I feel that the OIC trusts me and values me	1	2	3	4	5
A5_11	I feel that the Field supervisor trusts and values me	1	2	3	4	5
A5_12	I feel like I get regular feedback about CEBS activities	1	2	3	4	5
A5_13	I feel that people.in the community know about CEBS and why it is important	1	2	3	4	5

END OF INTERVIEW
THANK RESPONDENT FOR THEIR COOPERATION

HBMM CEBS EVALUATION
HEALTH FACILITY QUESTIONAIRE

Instructions:

1. *Use this tool to interview OICs about CEBS and POE activities.*
2. *Fill in the information below based on the provided sample listing*
3. *Record answers in the boxes.*

Identification		
B0_1	Respondent ID	
B0_2	County Name	
B0_3	District Name	
B0_4	Health Facility Name	

Interview Information			
B0_6	Interviewer Name		
B0_7	Time beginning of interview	|_||_|:|_||_|	
B0_8	Time at end of interview	|_||_|:|_||_|	
B0_9	Result	1. Completed 2. Partly Completed 3. Not present 4. Postponed 5. Refused 9. Other	☐
B0_10	Interview Date	__ __ / __ __ / __ __ __ __ M M D D Y Y Y Y	

Supervisor Signature

CONSENT			
PROMPT: Today we will be talking about Community Event Based Surveillance, or "CEBS" as a part of the IDSR strategy to improve disease surveillance in Liberia. As you may know, CEBS is a way to use Community Health Workers and Assistants to refer potential cases of priority disease to the health facility. We have been implementing CEBS in your county, and want to understand how we can make the program sustainable and produce better data. This is an evaluation of the program, not a supervision or performance assessment. Your responses will be kept completely anonymous.			
B0_10	Do you consent to the interview and wish to proceed?	1. Yes 2. No	☐
SECTION 1: BACKGROUND INFORMATION			
B1_1	What is your district of residence?		
B1_2	What is your current position?		
B1_3	What is your profession?	1. Physician 2. Physician's Assistant 4. Nurse 5. Midwife 9. Other	☐
B1_4	If other profession, specify		
B1_5	What level of schooling have you completed?	1. Medical School 2. Certificate Program 3. BSN/BA 4. High School 9. Other	☐
B1_5x	If other level of schooling, specify		

SECTION 2: BEHAVIORAL DETERMINANTS			
B2_1	Have you been trained in CEBS sometime in the past year (since summer 2015)?	1. Yes 2. No 8. Don't Know	☐
B2_2	Can you think of some reasons why your CEBS work is important to the community?	**1)**	
		2)	
		3)	
B2_3	In your opinion, are communities in your catchment area aware of and understand the importance of CEBS?	1. Yes 2. No 8. Don't Know	☐

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B2_4	In CEBS we use community triggers, which are symptoms which may indicate a sickness in the community and a need to go to the health facility. Can you please list all the triggers you can remember? *DO NOT READ ANSWERS. Check off the following as the respondent mentions them, and prompt for more.*	*Check off as the respondent mentions them:*	
		Any person with weakness in the legs and arms or not able to walk (polio)	☐
		Running stomach. Any person passing three or more watery pu-pu within one day (acute water diarrhea)	☐
		Diarrhea with blood, Any person passing bloodying pu-pu or slimy pu-pu with stomach pain (acute bloody diarrhea)	☐
		Any person who is bitten by a dog or other animal (rabies)	☐
		Any person with hot skin and spot-spot or red eyes (measles)	☐
		Any person who has fever with two or more of headaches, vomiting, runny stomach, weak in the body, yellow eyes, or died after serious sickness with fever and bleeding (viral hemorrhagic fever)	☐
		Any person with hot skin fever and stiff neck (meningitis)	☐
		Big belly death, woman who dies with big belly or within 42 days after baby is born when belly move (maternal death)	☐
		Jerking sickness. Baby who is normal at birth, then after two days is not able to suck starts jerking (neonatal tetanus)	☐
		Young baby death. Baby who dies at birth or within 28 days after birth (neonatal death)	☐
		Unknown health problems grouped together, that is happening to many many people or animals in the community	☐
		Any death in human or animals that you don't know why it happened	☐
B2_5	Describe some items you check during a weekly data quality audit of your CEBS data?	**1)**	☐
		2)	
		3)	

SECTION 3: Technical Determinants			
B3_1	Do you have a phone that can text?	1. Yes 2. No 8. Don't Know	☐
B3_2	Which of these networks can you use within the facility? *(read the list and mark all that apply)*	1. Cellcom 2. Lonestar 3. LibTelco 4. Novafone 5. No network available 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 9. ☐ **If not 9, skip to B3_3**
B3_2x	If other networks, specify		
B3_3	Do you have daily internet access?	1. Yes 2. No 8. Don't Know	☐
B3_4	Do you have a consistent electricity supply?	1. Yes 2. No 8. Don't Know	☐
B3_5	Does the facility have access to a functional laptop for storing data, checking mail, and looking at maps or graphs?	1. Yes 2. No 8. Don't Know	☐
B3_6	Do you have the priority disease clinical case definitions posted on the wall?	1. Yes 2. No 8. Don't Know	☐
B3_7	Do you have the community trigger definitions posted on the wall?	1. Yes 2. No 8. Don't Know	☐
B3_8	How often does your direct supervision or patient treatment take place in the community?	1. Often (weekly) 2. Sometimes (few times a month) 3. Rarely (few times a year) 4. Never	☐
B3_9	If you had to travel to a community within 5km of your health facility for any reason, how would you get there?	1. Walking 2. Motorbike 3. Taxi 4. Personal car 9. Other	☐ **If not 9, skip to B3_11**
B3_9x	If other, specify		
B3_10	Do you keep an updated registry of CHVs with phone numbers?	1. Yes 2. No 8. Don't Know	☐
B3_11	Do you have graphs of the priority disease trends within the catchment area updated in the last month?	1. Yes 2. No 8. Don't Know	☐

B3_12	When patients are referred to the health facility by a gCHV, how often do they have the CEBS trigger form with them when they arrive?	1. Often (every person) 2. Sometimes (most persons) 3. Rarely (some persons) 4. Never	☐
B3_13	Who is responsible for verifying CEBS triggers at your facility?		
B3_14	Who is responsible for filling out IDSR Case Alert forms at your facility?		
B3_15	How often do you fill out an IDSR Case Alert Form after a CEBS referral matches an IDSR case definition?	1. Often (every person) 2. Sometimes (most persons) 3. Rarely (some persons) 4. Never	☐
B3_16	What are some reasons that a trigger meeting the case definition might not be reported on an IDSR case alert form? *Prompt the respondent to come up with at least two*	**1)** **2)** **3)**	
B3_17	Do you have a place to keep CEBS forms at the facility?	1. Yes 2. No 8. Don't Know	☐
B3_18	In the past one month, have you run out of IDSR Case Alert or CEBS forms?	1. Yes 2. No 8. Don't Know	☐
B3_19	Are there any formal Point of Entry in your catchment area?	1. Yes 2. No 8. Don't Know	☐
B3_20	Have any gCHVs or screeners at POEs referred any suspect cases to you?	1. Yes 2. No 8. Don't Know	☐
B3_21	Besides the gCHV or screeners, do you receive priority disease referrals from traditional leaders or other people in the communities?	1. Yes 2. No 8. Don't Know	☐
B3_22	Do you have a room or area in the health facility for isolation?	1. Yes 2. No 8. Don't Know	☐

SECTION 4: Organizational Determinants			
B4_1	Who at your facility is primarily responsible for the supervision of the gCHVs?	1. Myself 2. Another clinician at the facility 3. IOM Implementing partner 4. District Health Team Member 8. Don't Know 9. Other	☐
B4_2	How often do you communicate with the gCHV?	1. Often (weekly) 2. Sometimes (a few times a month) 3. Rarely (once in a while) 4. Never	☐
B4_3	How often do you communicate to the gCHV about the outcome of a referral and any next steps?	1. Often (every case) 2. Sometimes (most cases) 3. Rarely (some cases) 4. Never	☐
B4_4a	Is CEBS data used to inform community education and mobilization?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to B4_5**
B4_4b	Can you give me an example of when CEBS data was used to inform community education and mobilization?		
B4_5	How often does the DSO communicate with you about IDSR cases?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
B4_6a	How often does the DSO ask about cases of priority disease that you saw?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
B4_6b	How often does the DSO talk to you about the data completeness, quality, and timeliness of IDSR reporting?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
B4_6c	How often does the DSO look at your HMIS logbooks to see if there are any other cases of interest?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
B4_6d	How often does the DSO look at the CEBS reporting forms?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐

B4_7	Tell me the main challenges of your job for CEBS? *Prompt the respondent to come up with at least two*	**1)**	
		2)	
		3)	
B4_8	Do you have suggestions for how CEBS activities could be improved? *Prompt the respondent to come up with at least two*	**1)**	
		2)	
		3)	
B4_9	What is the biggest IDSR priority disease of concern in your catchment area?		
B4_10	Are there specific communities at high risk of disease or public health conditions within your catchment area?	1. Yes 2. No 8. Don't Know	☐
B4_11	Can you name the top at-risk communities? *Prompt the respondent to come up with at least two*	**1)**	
		2)	
		3)	
B4_12a	Have you been involved in any outbreak response activities with the DSO?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to B4_13**
B4_12b	Can you give me an example of an outbreak response activity with the DSO?		
B4_13	In the last one month, has the DSO given you feedback on community reporting?	1. Yes 2. No 8. Don't Know	☐

Section 5

PROMPT: For the last section, I will give you statements. You will tell me to what extent do you agree with the following scale?

(read the scale, and circle the answers)

		1. Strongly Disagree	2. Disagree	3. Neither Disagree nor Agree	4. Agree	5. Strongly Agree
B5_1	I feel discouraged when the data that I collect/record is not used for taking action	1	2	3	4	5
B5_2	Collecting data is meaningful/useful for me	1	2	3	4	5
B5_3	I feel that the data I collect is important for the community	1	2	3	4	5
B5_4	I feel that collecting data is a burden, I have better things to do	1	2	3	4	5
B5_5	My work of collecting data is appreciated and valued by my supervisors	1	2	3	4	5
B5_6	People in the community trust the health facility to provide health services	1	2	3	4	5
B5_7	I feel people trust and talk to me about their health conditions	1	2	3	4	5
B5_8	People sometimes face stigma from the community about health conditions	1	2	3	4	5
B5_9	I feel that I get regular feedback about IDSR data quality from the District	1	2	3	4	5
B5_10	I feel that supervision and mentorship of CHVs is a burden	1	2	3	4	5
B5_11	I feel that I have support in addressing potential outbreaks in my catchment area	1	2	3	4	5
B5_12	I feel that I have the necessary training or experience to check data quality	1	2	3	4	5
B5_13	I can use data for identifying service performance gaps and setting performance targets	1	2	3	4	5
B5_14	I can use data for providing feedback to CHVs	1	2	3	4	5
B5_15	I feel that my supervisors and policy-makers demand complete, timely, accurate, relevant and validated IDSR and CEBS data	1	2	3	4	5
B5_16	I feel that stigma about certain diseases in the community is a barrier to involving gCHVs in health education	1	2	3	4	5

END OF INTERVIEW

HBMM Evaluation
DISTRICT QUESTIONNAIRE

Instructions:

1. *Use this tool to interview DSOs about CEBS and POE activities.*
2. *Record answers in the boxes.*

Identification		
E0_1	Respondent ID	
E0_2	County Name	
E0_3	District Name	

Interview Information			
E0_4	Interviewer Name		
E0_5	Time beginning of interview	|_||_|:|_||_|	
E0_6	Time at end of interview	|_||_|:|_||_|	
E0_7	Result	1. Completed 2. Partly Completed 3. Not present 4. Postponed 5. Refused 9. Other	☐
E0_8	Interview Date	__ __ / __ __ / __ __ __ __ M M D D Y Y Y Y	
	Comments		

Supervisor Signature	

CONSENT			
PROMPT: Today we will be talking about Community Event Based Surveillance and Point of Entry activities, as a part of the IDSR strategy to improve disease surveillance in Liberia. As you may know, CEBS and POE screening is a way to use Community Health Workers and Assistants to refer potential cases of priority disease to the health facility. We have been implementing CEBS in your county, and want to understand how we can make the program sustainable and produce better data. This is an evaluation of the program, not a supervision or performance assessment. Your responses will be kept completely anonymous.			
E0_10	Do you consent to the interview and wish to proceed?	1. Yes 2. No	☐

First we will start by asking some basic background information.

SECTION 1: BACKGROUND INFORMATION			
E1_1	What is your district of residence?		
E1_2	What is your profession?	1. Physician 2. Physician's Assistant 4. Nurse 5. Midwife 6. EHT 9. Other	☐ **If not 9, skip to E1_3**
E1_2x	If other profession, specify		
E1_3	What level of schooling have you completed?	1. Medical School 2. Masters 3. Certificate Program 4. BSN/BA 5. High School 9. Other	☐ **If not 9, skip to E1_4**
E1_3x	If other level of schooling, specify		
E1_4	When did you first start working as a DSO? *(month and year)*		

SECTION 2: BEHAVIORAL DETERMINANTS			
E2_1	Have you been trained in frontline FETP in the past year?	1. Yes 2. No 8. Don't Know	☐
E2_2	Have you been trained in Community Event-Based Surveillance sometime in the past year (since summer 2015)?	1. Yes 2. No 8. Don't Know	☐
E2_3	Can you think of three reasons why your CEBS work is important to the health of the district? *Prompt for at least 2 answers*	**1)**	
		2)	
		3)	
E2_4	In CEBS we use community triggers, which are symptoms which may indicate a sickness in the community and a need to go to the health facility. Can you please list all the triggers you can remember? *DO NOT READ ANSWERS. Check off the following as the respondent mentions them, and prompt for more.*	*Check off as the respondent mentions them:*	
		Any person with weakness in the legs and arms or not able to walk (polio)	☐
		Running stomach. Any person passing three or more watery pu-pu within one day (acute water diarrhea)	☐
		Diarrhea with blood, Any person passing bloodying pu-pu or slimy pu-pu with stomach pain (acute bloody diarrhea)	☐
		Any person who is bitten by a dog or other animal (rabies)	☐
		Any person with hot skin and spot-spot or red eyes (measles)	☐
		Any person who has fever with two or more of headaches, vomiting, runny stomach, weak in the body, yellow eyes, or died after serious sickness with fever and bleeding (viral hemorrhagic fever)	☐
		Any person with hot skin fever and stiff neck (meningitis)	☐
		Big belly death, woman who dies with big belly or within 42 days after baby is born when belly move (maternal death)	☐
		Jerking sickness. Baby who is normal at birth, then after two days is not able to suck starts jerking (neonatal tetanus)	☐
		Young baby death. Baby who dies at birth or within 28 days after birth (neonatal death)	☐

		Unknown health problems grouped together, that is happening to many many people or animals in the community	☐
		Any death in human or animals that you don't know why it happened	☐
E2_5	Describe three activities you would conduct during a data quality audit of CEBS or IDSR data *Prompt for at least 2 answers*	**1)**	
		2)	
		3)	

SECTION 3: Technical Determinants			
E3_1	Do you have a phone that can send texts?	1. Yes 2. No 8. Don't Know	☐
E3_2	Which of these networks can you use within your district? *(read the list and mark all that apply)*	1. Cellcom 2. Lonestar 3. LibTelco 4. Novafone 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 9. ☐ **If not 9, skip to E3_3**
E3_2x	If other networks, specify		
E3_3a	Are you able to access internet within your district?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E3_4**
E3_3b	How do you access the internet?	1. Modem 2. Hotspot/Cellphone 3. Internet at the district health office 4. Internet at the county health office or county EOC 9. Other (specify)	☐ **If not 9, skip to E3_4**
E3_3x	If another source of internet is available, specify		
E3_4	Do you have a district office or room where you work?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E3_6a**
E3_5a	Do you have the priority disease clinical case definitions posted on the wall of your district office?	1. Yes 2. No 8. Don't Know	☐

E3_5b	Do you have the community trigger definitions posted on the wall of your district office?	1. Yes 2. No 8. Don't Know	☐
B3_5c	Do you have a daily electricity supply in your district office?	1. Yes 2. No 8. Don't Know	☐
E3_6a	Do you keep a registry of CHVs with contact information?	1. Yes 2. No 8. Don't Know	☐
E3_6b	Do you have a copy of the most recent IDSR Technical Guidelines?	1. Yes 2. No 8. Don't Know	☐
E3_6c	Do you have a set of CEBS job aids?	1. Yes 2. No 8. Don't Know	☐
E3_7	Do you have access to a functional laptop for storing data, checking mail, and looking at maps or graphs?	1. Yes 2. No 8. Don't Know	☐
E3_8	Do you have a functional motorbike which was provided by the Ministry of Health or partner?	1. Yes 2. No 8. Don't Know	☐

E3_9	Sometimes a health facility receives a priority case, but it does not get captured in the IDSR database. Can you think of some reasons why? *(Prompt further for at least 2 answers)*	**1)** **2)** **3)**	
E3_10	In the past one month, have you run out of recently updated version of the IDSR Case Alert Form?	1. Yes 2. No 8. Don't Know	☐
E3_11	Do you have a place where you could store completed CEBS forms?	1. Yes 2. No 8. Don't Know	☐
E3_12a	Are there any formal POEs within in your district?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E3_14**
E3_12b	If you have a formal POE, how often do you meet with POE officials to discuss IDSR data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E3_12c	Who is present at the POE meetings?	1. Port health official 2. BIN officer 3. Screener 9. Other	1. ☐ 2. ☐ 3. ☐ 9. ☐ **If not 9, skip to E3_12d**
E3_12d	Which other person is at these meetings?		
E3_13	Do you provide routine supervision to screeners at POEs?	1. Yes 2. No 8. Don't Know	☐
E3_14	Do you keep a record of which IDSR suspect cases were detected at the community level?	1. Yes 2. No 8. Don't Know	☐
E3_15	Do you keep a record of which cases have recently travelled from country to country?	1. Yes 2. No 8. Don't Know	☐

SECTION 4: Organizational Determinants			
E4_1	Do you have a supervision tool to evaluate OIC and POE performance in IDSR activities?	1. Yes 2. No 8. Don't Know	☐
E4_2	On average, how often do you communicate with the health facilities to find out about IDSR cases?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E4_3	How often do you give feedback to OICs about CEBS and POE triggers?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E4_4	Which of the following sources of information do you check weekly? *Select all that apply*	1. OIC or SFP tells me (oral report) 2. HMIS ledgers 3. IDSR Weekly Ledger 4. IDSR Case Alert Forms 5. CEBS forms 6. Direct reports from community 7. Direct reports from POEs 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐ 7. ☐ 9. ☐ **If not 9, skip to E4_5**
E4_4x	If other source of information, specify		
E4_5a	How often do you meet with the DHO to discuss IDSR performance and reporting of health facilities within your district?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E4_5b	Do you talk about CEBS or POE data at these meetings?	1. Yes 2. No 8. Don't Know	☐
E4_6	How often do you have routine (weekly or monthly) meetings with the entire DHT to review IDSR data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E4_7a	How often do you meet with the CSO to review IDSR data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
E4_7b	How often do you meet with the CSO to review CEBS and POE data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never	☐

		8. Don't Know	
E4_8	How often does the CSO talk to you about the data completeness, quality, and timeliness of your IDSR reporting?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐

E4_9a	Do you attend community health committee meetings?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E4_10a**
E4_9b	Can you give me an example of what was discussed at the Community Health Committee Meeting?		
E4_10a	Are you a part of the CEBS implementation team?	1. Yes 2. No 8. Don't Know	☐ **If not 2, skip to E4_11**
E4_10b	Can you give me an example of what was discussed at the CEBS implementation team meeting?		
E4_11	Have you ever worked with a gCHV to detect and respond to cases in a community?	1. Yes 2. No 8. Don't Know	☐
E4_12	Have you ever worked with a gCHV to promote behavior change in a community?	1. Yes 2. No 8. Don't Know	☐
E4_13a	Is CEBS data used to inform community education and mobilization within communities in your district?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E4_14**
E4_13b	Can you give me an example of when CEBS data was used to inform community education and mobilization?		
E4_14	Is CEBS data used to identify high risk communities within your district?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to E4_6**
E4_15	Based on your CEBS data, what communities are at the highest risk of disease in your district?		
E4_16	Do you have graphs updated within the last month with the priority disease trends within the catchment area?	1. Yes 2. No 8. Don't Know	☐

E4_17	Who is responsible for verifying CEBS triggers meet the community case definition?	
E4_18	Who is responsible for checking to make sure a suspect case meets the clinical case definition?	
E4_19	Who is responsible for filling out IDSR Case Alert forms?	
E4_20	Tell me three challenges of your job in relation to CEBS? *(Prompt further for at least 2 answers)*	**1)**
		2)
		3)
E4_21	Do you have suggestions for how CEBS activities could be improved? *(Prompt further for at least 2 answers)*	**1)**
		2)
		3)

Section 5
PROMPT: For the last section, I will give you statements. You will tell me to what extent do you agree with the following scale?
(read the scale, and circle the answers)

		1. Strongly Agree	2. Agree	3. Neither Disagree nor Agree	4. Disagree	5. Strongly Disagree
E5_1	I feel discouraged when the data that I collect/record is not used for taking action	1	2	3	4	5
E5_2	Collecting data is meaningful/useful for me	1	2	3	4	5
E5_3	I feel that the data I collect is important for my district	1	2	3	4	5
E5_4	I feel that collecting data is a burden, I have better things to do	1	2	3	4	5
E5_5	My work of collecting data is appreciated and valued by my supervisors	1	2	3	4	5
E5_6	People in the community trust the health facility to provide health services	1	2	3	4	5
E5_7	I feel people trust and talk to me about their health conditions	1	2	3	4	5
E5_8	People sometimes face stigma from the community about health conditions	1	2	3	4	5
E5_9	I feel that I get regular feedback about IDSR data quality from the county	1	2	3	4	5
E5_10	I feel that I get regular feedback about CEBS and POE data quality from the county	1	2	3	4	5
E5_11	I feel that supervision and mentorship of OIC/SFPs is a burden	1	2	3	4	5

E5_12	I feel that I have support in addressing potential outbreaks in my catchment area	1	2	3	4	5
E5_13	I feel that I have the necessary training or experience to check data quality	1	2	3	4	5
E5_14	I can use data for identifying service performance gaps and setting performance targets	1	2	3	4	5
E5_15	I can use data for providing feedback to OICs and POE staff	1	2	3	4	5
E5_16	I feel that my supervisors and policy-makers demand complete, timely, accurate, relevant and validated IDSR and CEBS data	1	2	3	4	5
E5_17	I feel that some OICs in my area do not understand why CEBS is important to their catchment area	1	2	3	4	5
E5_18	I feel that the CHV is a helpful resource when working in the community	1	2	3	4	5
E5_19	I feel comfortable in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
E5_20	I feel that I need more training in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
E5_21	I feel that I know how to create a line list when dealing with an outbreak	1	2	3	4	5
E5_22	I feel that I know how to create spot maps	1	2	3	4	5
E5_23	I feel that communities in my area understand why CEBS is important to them	1	2	3	4	5
E5_24	I feel that I understand how CEBS data is captured and feeds into IDSR	1	2	3	4	5

THANK RESPONDENT FOR THEIR COOPERATION

HBMM Evaluation
COUNTY QUESTIONNAIRE

Instructions:

1. *Use this tool to interview CSOs about CEBS and POE activities.*
2. *Record answers in the boxes.*

Identification		
F0_1	Respondent ID	
F0_2	County Name	
F0_3	District Name	

Interview Information			
F0_4	Interviewer Name		
F0_5	Time beginning of interview	|_||_|:|_||_|	
F0_6	Time at end of interview	|_||_|:|_||_|	
F0_7	Result	1. Completed 2. Partly Completed 3. Not present 4. Postponed 5. Refused 9. Other	☐
F0_8	Interview Date	__ __ / __ __ / __ __ __ __ M M D D Y Y Y Y	

Supervisor Signature

CONSENT			
PROMPT: Today we will be talking about Community Event Based Surveillance and Point of Entry activities, as a part of the IDSR strategy to improve disease surveillance in Liberia. As you may know, CEBS and POE screening is a way to use Community Health Workers and Assistants to refer potential cases of priority disease to the health facility. We have been implementing CEBS in your county, and want to understand how we can make the program sustainable and produce better data. This is an evaluation of the program, not a supervision or performance assessment. Your responses will be kept completely anonymous.			
F0_10	Do you consent to the interview and wish to proceed?	1. Yes 2. No	☐

First we will start by asking some basic background information.

SECTION 1: BACKGROUND INFORMATION			
F1_1	What is your profession?	1. Physician 2. Physician's Assistant 4. Nurse 5. Midwife 9. Other	☐ **If not 9, skip to F1_2**
F1_1x	If other profession, specify		
F1_2	What level of schooling have you completed?	1. Medical School 2. Certificate Program 3. BSN/BA 4. High School 9. Other	☐ **If not 9, skip to F1_3**
F1_2x	If other level of schooling, specify		
F1_3	When did you first start working as a DSO?		

SECTION 2: BEHAVIORAL DETERMINANTS			
F2_1	Have you been trained in frontline FETP in the past year?	1. Yes 2. No 8. Don't Know	☐
F2_2	Have you been trained in Community Event-Based Surveillance sometime in the past year (since summer 2015)?	1. Yes 2. No 8. Don't Know	☐
F2_3	Can you think of three reasons why your CEBS work is important to the health of the county?	**1)**	
		2)	
		3)	
F2_4	In CEBS we use community triggers, which are symptoms which may indicate a sickness in the community and a need to go to the health facility. Can you please list all the triggers you can remember? *DO NOT READ ANSWERS. Check off the following as the respondent mentions them, and prompt for more.*	*Check off as the respondent mentions them:*	
		Any person with weakness in the legs and arms or not able to walk (polio)	☐
		Running stomach. Any person passing three or more watery pu-pu within one day (acute water diarrhea)	☐
		Diarrhea with blood, Any person passing bloodying pu-pu or slimy pu-pu with stomach pain (acute bloody diarrhea)	☐
		Any person who is bitten by a dog or other animal (rabies)	☐
		Any person with hot skin and spot-spot or red eyes (measles)	☐
		Any person who has fever with two or more of headaches, vomiting, runny stomach, weak in the body, yellow eyes, or died after serious sickness with fever and bleeding (viral hemorrhagic fever)	☐
		Any person with hot skin fever and stiff neck (meningitis)	☐
		Big belly death, woman who dies with big belly or within 42 days after baby is born when belly move (maternal death)	☐
		Jerking sickness. Baby who is normal at birth, then after two days is not able to suck starts jerking (neonatal tetanus)	☐
		Young baby death. Baby who dies at birth or within 28 days after birth (neonatal death)	☐

		Unknown health problems grouped together, that is happening to many many people or animals in the community	☐
		Any death in human or animals that you don't know why it happened	☐
F2_5	Describe three activities you would conduct during a data quality audit of CEBS or IDSR data	**1)**	☐
		2)	
		3)	

SECTION 3: Technical Determinants			
F3_1	Do you have a phone that can send texts?	1. Yes 2. No 8. Don't Know	☐
F3_2	Which of these networks can you use within your county? *(read the list and mark all that apply)*	1. Cellcom 2. Lonestar 3. LibTelco 4. Novafone 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 9. ☐ **If not 9, skip to F3_3**
F3_2x	If other networks, specify		
F3_3a	Are you able to access internet within your county?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to F3_4**
F3_3b	How do you access the internet?	1. Modem 2. Hotspot/Cellphone 3. Internet at the district health office 4. Internet at the county health office or county EOC 9. Other (specify)	☐ **If not 9, skip to F3_4**
F3_3x	If another source of internet is available, specify		
F3_4	Do you have a county office or room where you work?	1. Yes 2. No 8. Don't Know	☐ **If 2, skip to F3_6a**
F3_5a	Do you have the priority disease clinical case definitions posted on the wall of your county office?	1. Yes 2. No 8. Don't Know	☐

F3_5b	Do you have the community trigger definitions posted on the wall of your county office?	1. Yes 2. No 8. Don't Know	☐
B3_5c	Do you have daily electricity supply in your county office?	1. Yes 2. No 8. Don't Know	☐
F3_6a	Do you have a copy of the most recent IDSR Technical Guidelines?	1. Yes 2. No 8. Don't Know	☐
F3_6b	Do you have a set of CEBS job aids?	1. Yes 2. No 8. Don't Know	☐
F3_7	Do you have access to a functional laptop for storing data, checking mail, and looking at maps or graphs?	1. Yes 2. No 8. Don't Know	☐
F3_8	Do you have a vehicle you can use for your IDSR work?	1. Yes 2. No 8. Don't Know	☐

F3_9	Sometimes a health facility receives a priority case, but it does not get captured in the IDSR database. Can you think of some reasons why? *(Prompt further for at least 2 answers)*	**1)** **2)** **3)**	
F3_10	In the past one month, have you run out of the recently updated version of the IDSR Case Alert Form?	1. Yes 2. No 8. Don't Know	☐
F3_11	Are there any formal POEs within in your county?	1. Yes 2. No 8. Don't Know	☐ **If not 2, skip to E3_14**
F3_12a	If you have a formal POE, how often do you meet with POE officials to discuss health screening?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐ **If not 5 or 8, skip to E3_14**
E3_12b	Who is present at the POE meetings? *(select all that apply)*	1. Port health official 2. BIN officer 3. Screener 9. Other	1. ☐ 2. ☐ 3. ☐ 9. ☐ **If not 9, skip to E3_14**
E3_12c	Which other persons are present at POE meetings?		
F3_14	Do you provide routine supervision to screeners and PHOs at POEs?	1. Yes 2. No 8. Don't Know	☐
F3_15	Do you keep a record of which cases were detected at the community level?	1. Yes 2. No 8. Don't Know	☐
F3_16	Do you keep a record of which cases have recently travelled from country to country?	1. Yes 2. No 8. Don't Know	☐

SECTION 4: Organizational Determinants			
F4_1	Do you have a supervision tool to evaluate DSO and OIC performance in IDSR activities?	1. Yes 2. No 8. Don't Know	☐
F4_2	On average, how quickly do you find out about IDSR suspect cases from the district?	1. Within a day 2. Within a few days 3. Within a week 4. Within a month 5. Never 8. Don't Know	☐
F4_3	How often do you give feedback to DSOs about CEBS and POE case reports?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
F4_5a	How often do you meet with the CHO to discuss IDSR performance and reporting of health facilities within your district?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐ **If not 5 or 8, skip to F4_6**
F4_5b	Do you talk about CEBS or POE data at these meetings?	1. Yes 2. No 8. Don't Know	☐
F4_6	How often do you have routine (weekly or monthly) meetings with your entire CHT to review IDSR data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
F4_7	How often do you communicate with DPC about IDSR and CEBS data?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
F4_8	How often does DPC give you feedback about the data completeness, quality, and timeliness of your IDSR reporting?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
F4_9	Are you a part of the CEBS implementation team?	1. Yes 2. No 8. Don't Know	☐ **If not 2 or 8, skip to F4_13**
F4_10a	Can you give me an example of what is discussed at the CEBS implementation team meeting?		
F4_10b	Who attends the CEBS implementation meetings?		

F4_11	How often do you talk to the CHDD about CEBS implementation, data, and operations?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
F4_12 a	Is CEBS data used to inform community education and mobilization within communities in your district?	1. Yes 2. No 8. Don't Know	☐
E4_12 b	Can you give me an example of when CEBS data was used to inform community education and mobilization?		
F4_13 a	Is CEBS data used to identify high risk communities within your county?	1. Yes 2. No 8. Don't Know	☐
F4_13 b	Based on your CEBS data, what communities are at the highest risk of disease in your county?		
F4_14	Do you have graphs updated within the last month with the priority disease trends within the county?	1. Yes 2. No 8. Don't Know	☐
F4_15	Who is responsible for verifying CEBS triggers?		
.F4_1 7	Who is responsible for checking to make sure a suspect case meets the clinical case definition?		
F4_18	Who is responsible for filling out IDSR Case Alert forms?		
F4_19	Tell me three challenges of your job in relation to CEBS? *(Prompt further for at least 2 answers)*	**1)** **2)** **3)**	
F4_20	Do you have suggestions for how CEBS activities could be improved? *(Prompt further for at least 2 answers)*	**1)** **2)** **3)**	

Section 5 **PROMPT: For the last section, I will give you statements. You will tell me to what extent do you agree with the following scale?** *(read the scale, and circle the answers)*						
		1. Strongly Agree	**2. Agree**	**3. Neither Disagree nor Agree**	**4. Disagree**	**5. Strongly Disagree**
F5_1	I feel discouraged when the data that I collect/record is not used for taking action	1	2	3	4	5
F5_3	Collecting data is meaningful/useful for me	1	2	3	4	5
F5_4	I feel that the data I collect is important for the county	1	2	3	4	5
F5_5	I feel that collecting data is a burden, I have better things to do	1	2	3	4	5
F5_6	My work of collecting data is appreciated and valued by my supervisors	1	2	3	4	5
F5_7	People in the community trust the health facility to provide health services	1	2	3	4	5
F5_8	I feel people trust and talk to me about their health conditions	1	2	3	4	5
F5_9	People sometimes face stigma from the community about health conditions	1	2	3	4	5
F5_10	I feel that I get regular feedback about IDSR data quality from the county	1	2	3	4	5
F5_11	I feel that supervision and mentorship of OIC/SFPs is a burden	1	2	3	4	5
F5_12	I feel that I have support in addressing potential outbreaks in my county	1	2	3	4	5
F5_13	I feel that I have the necessary training or experience to check data quality	1	2	3	4	5
F5_14	I can use data for identifying service performance gaps and setting performance targets	1	2	3	4	5
F5_15	I can use data for providing feedback to staff	1	2	3	4	5
F5_16	I feel that my supervisors and policy-makers demand complete, timely, accurate, relevant and validated IDSR and CEBS data	1	2	3	4	5
F5_17	I feel that some DSOs in my area do not understand why CEBS is important	1	2	3	4	5
F5_18	I feel that CHVs are a helpful resource when working in the community	1	2	3	4	5
F5_19	I feel comfortable in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
F5_20	I feel that I need more training in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
F5_21	I know how to create a line list when dealing with an outbreak	1	2	3	4	5
F5_22	I know how to create spot maps	1	2	3	4	5
F5_23	I feel that communities in my area do not understand why CEBS is important to them	1	2	3	4	5
E5_24	I feel that I understand how CEBS data is captured and feeds into IDSR	1	2	3	4	5

HBMM Evaluation
NATIONAL QUESTIONNAIRE

Instructions:

1. *Use this tool to interview CSOs about CEBS and POE activities.*
2. *Record answers in the boxes.*

Identification		
G0_1	Respondent ID	
G0_2	County Name	
G0_3	District Name	

Interview Information			
G0_4	Interviewer Name		
G0_5	Time beginning of interview	|_||_|:|_||_|	
G0_6	Time at end of interview	|_||_|:|_||_|	
G0_7	Result	1. Completed 2. Partly Completed 3. Not present 4. Postponed 5. Refused 9. Other	☐
G0_8	Interview Date	__ __ / __ __ / __ __ __ __ M M D D Y Y Y Y	

Supervisor Signature

CONSENT			
PROMPT: Today we will be talking about Community Event Based Surveillance and Point of Entry activities, as a part of the IDSR strategy to improve disease surveillance in Liberia. As you may know, CEBS and POE screening is a way to use Community Health Workers and Assistants to refer potential cases of priority disease to the health facility. We have been implementing CEBS in your county, and want to understand how we can make the program sustainable and produce better data. This is an evaluation of the program, not a supervision or performance assessment. Your responses will be kept completely anonymous.			
G0_10	Do you consent to the interview and wish to proceed?	1. Yes 2. No	☐

First we will start by asking some basic background information.

SECTION 1: BACKGROUND INFORMATION			
G1_1	What is your profession?	1. Physician 2. Physician's Assistant 4. Nurse 5. Midwife 6. Public health professional 9. Other	☐
G1_1x	If other profession, specify		
G1_2	What is your position?		
G1_3	Which unit of the MOH do you work in?	1. DPC 2. CHSD (Community Health) 3. HMER 4. Health Promotion 5. Family Health 9. Other	☐
G1_3x	If another unit, specify		
G1_4	What level of schooling have you completed?	1. Medical School 2. Certificate Program 3. BSN/BA 4. High School 9. Other	☐
G1_4x	If other level of schooling, specify		

SECTION 2: BEHAVIORAL DETERMINANTS (for DPC only)			
G2_1	In CEBS we use community triggers, which are symptoms which may indicate a sickness in the community and a need to go to the health facility. Can you please list all the triggers you can remember? *DO NOT READ ANSWERS. Check off the following as the respondent mentions them, and prompt for more.*	*Check off as the respondent mentions them:*	
		Any person with weakness in the legs and arms or not able to walk (polio)	☐
		Running stomach. Any person passing three or more watery pu-pu within one day (acute water diarrhea)	☐
		Diarrhea with blood, Any person passing bloodying pu-pu or slimy pu-pu with stomach pain (acute bloody diarrhea)	☐
		Any person who is bitten by a dog or other animal (rabies)	☐
		Any person with hot skin and spot-spot or red eyes (measles)	☐
		Any person who has fever with two or more of headaches, vomiting, runny stomach, weak in the body, yellow eyes, or died after serious sickness with fever and bleeding (viral hemorrhagic fever)	☐
		Any person with hot skin fever and stiff neck (meningitis)	☐
		Big belly death, woman who dies with big belly or within 42 days after baby is born when belly move (maternal death)	☐
		Jerking sickness. Baby who is normal at birth, then after two days is not able to suck starts jerking (neonatal tetanus)	☐
		Young baby death. Baby who dies at birth or within 28 days after birth (neonatal death)	☐
		Unknown health problems grouped together, that is happening to many many people or animals in the community	☐
		Any death in human or animals that you don't know why it happened	☐
G2_2	Describe three activities you would conduct during a data quality audit of CEBS or IDSR data	**1)**	☐
		2)	
		3)	
G2_3	Sometimes a health facility receives a priority case, but it does not get captured in the IDSR	**1)**	
		2)	

	database. Can you think of some reasons why? *(Prompt further for at least 2 answers)*	**3)**

G2_3	What steps would you take after finding a silent district for CEBS, or discrepancy between CEBS and IDSR reporting?	**1)**
		2)
		3)
		4)
		5)
G2_4	Who is responsible for verifying CEBS triggers?	
G2_5	Who is responsible for verifying a case meets a case definition?	
G2_6	Who is responsible for filling out IDSR Case Alert forms?	

THIS AREA

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SECTION 3: OPERATIONAL CONTROL (for DPC only)			
G3_1	Do you have a supervision tool for CEBS which is integrated into the overall IDSR and CHSD programs?	1. Yes 2. No 8. Don't Know	☐
G3_2	How often do you review the data completeness, quality, and timeliness of CEBS?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_3	How often do you discuss data completeness, quality, and timeliness of IDSR reporting of counties with:	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_4	How often do you give feedback on performance of IDSR and CEBS activities in counties to:	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_5	How often do you have routine meetings within DPC to review CEBS data	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_6	How often do you have routine meetings within DPC to review POE and travel history information	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_7	How often do you have routine meetings within DPC to review IDSR case information	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_8	How often do you review the data completeness, quality, and timeliness of CEBS?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G3_9	Do you attend community health committee meetings?	1. Yes 2. No 8. Don't Know	☐
G3_10	In your opinion, what is the most important indicator of CEBS performance?		
G3_11	Is CEBS data used to identify high risk communities within your county?	1. Yes 2. No	☐

		8. Don't Know	
G3_12	What is the biggest IDSR priority disease of concern in your county?		
G3_13	Do you have graphs updated within the last month with the priority disease trends within the catchment area?	1. Yes 2. No 8. Don't Know	☐
G3_14	Who is primarily responsible for the implementation of CEBS within a county?		
G3_15	Who is primarily responsible for implementation and coordination of CEBS at the national level?		
SECTION 4: ORGANIZATIONAL DETERMINANTS			
G4_1a	Which of these meetings have you attended in the past 1 month?:	1. CEBS technical working group 2. National Surveillance Technical Committee 3. MNDSR Technical Committee 4. CBIS Technical Work Group 5. HMER Technical Working Group 6. Health Workforce Steering Committee	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 6. ☐
G4_1b	How often do you communicate with the CEBS Implementation team?	1. Daily 2. Weekly 3. Monthly 4. Rarely 5. Never 8. Don't Know	☐
G4_2	Have you participated in Community Event-Based Surveillance training sometime in the past year (since summer 2015)?	1. Yes 2. No 8. Don't Know	☐
G4_3	Can you think of three reasons why CEBS is important to the health of the country?	**1)** **2)** **3)**	
G4_5	Based on your current position, which of the following roles do you play in CEBS implementation in Liberia?	1. Technical support 2. Operational support 3. Supervision 4. Monitoring and Evaluation 5. User of the resulting information 9. Other	1. ☐ 2. ☐ 3. ☐ 4. ☐ 5. ☐ 9. ☐ **If not 9, skip to G4_6**
G4_5x	What other role do you play?		
G4_6	Who do you talk to in order to access CEBS information?		

G4_7	What aspects of CEBS are captured in the routine CBIS system?	
G4_8	What aspects of CEBS are captured in the routine IDSR information?	
G4_9	What is your role in: Building relationships, communication, and coordination with other community key informants, resource persona, and existing formal and informal networks for information dissemination and reporting	
G4_10	What is your role in: Community mapping and population registration including birth recording	
G4_11	What is your role in: Community death recording with special emphasis on maternal and neonatal death	
G4_12	What is your role in: Identify reporting priority diseases and event triggers as they occur in the community, including early case detection through active case finding	
G4_13	What is your role in: Adherence to IPC standard practices and community awarenss of general IPC principles	
G4_14	Have you ever used CEBS data to inform community education and mobilization strategies?	
G4_15	Tell me three challenges of your job in relation to CEBS? *(Prompt further for at least 2 answers)*	**1)** **2)** **3)**
G4_16	Do you have suggestions for how CEBS activities could be improved?	**1)** **2)**

	(Prompt further for at least 2 answers)	**3)**
G4_17	Describe three activities you would conduct during a data quality audit of CEBS or IDSR data	**1)**
		2)
		3)

Section 5 **PROMPT: For the last section, I will give you statements. You will tell me to what extent do you agree with the following scale?** *(read the scale, and circle the answers)*						
		1. Strongly Agree	**2. Agree**	**3. Neither Disagree nor Agree**	**4. Disagree**	**5. Strongly Disagree**
G5_1	I feel that I get regular feedback about IDSR data quality from the county	1	2	3	4	5
G5_2	I feel that supervision and mentorship of OIC/SFPs is a burden	1	2	3	4	5
G5_3	I feel that I have support in addressing potential outbreaks in my catchment area	1	2	3	4	5
G5_4	I feel that I have the necessary training or experience to check data quality	1	2	3	4	5
G5_5	I can use data for identifying service performance gaps and setting performance targets	1	2	3	4	5
G5_6	I can use data for providing feedback to staff	1	2	3	4	5
G5_7	I feel that my supervisors and policy-makers demand complete, timely, accurate, relevant and validated IDSR and CEBS data	1	2	3	4	5
G5_8	I feel that CHTs do not understand why CEBS is important	1	2	3	4	5
G5_9	I feel that CHVs are a helpful resource when working in the community	1	2	3	4	5
G5_10	I feel comfortable in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
G5_11	I feel that I need more training in data cleaning, management, and analysis activities for surveillance information	1	2	3	4	5
G5_12	I know how to create and use risk hotspot maps	1	2	3	4	5
G5_13	I feel that units at the MOH besides mine support implementation and value CEBS	1	2	3	4	5
G5_14	I feel that CEBS implementation, supervision, and data use is well coordinated between units at the MOH	1	2	3	4	5

END OF INTERVIEW
THANK RESPONDENT FOR THEIR COOPERATION

Curriculum Vitae

TASHRIK AHMED

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EDUCATION

Johns Hopkins University, Bloomberg School of Public Health
Ph.D., International Health

The George Washington University, Mailman School of Public Health
Masters of Public Health, Epidemiology

Purdue University, Weldon School of Biomedical Engineering
Bachelor of Science, Biomedical Engineering

CURRENT POSITION

World Bank- International Bank for Reconstruction and Development 2018-Current
Consultant – Central Asian Regional Health Team (HNP/DECHD) Dushanbe, Tajikistan

- Preparation of a report summarizing the impact of performance based financing on quality and coverage of primary health care in rural Tajikistan
- Coordinated survey firms and oversaw quality control and methodology during field implementation of a large multi-treatment multi-cluster study
- Developed final empirical approach and final database for key health indicators

RELEVANT EXPERIENCE

Johns Hopkins Bloomberg School of Public Health 2015-2018
Country Director – Health Information Systems and Surveillance Strengthening Monrovia, Liberia

Technical lead and co-author for CDC cooperative agreement supporting the Ministry of Health in strengthening health systems in the wake of the West African EVD outbreak. Key achievements included:

- Supported and adapted HMN evaluation for health information sector evaluation
- Policy evaluation and strategic planning for disease surveillance, health informatics, research, ICT, community health, and reproductive health resulting in 5-year costed strategic and operational plans
- Developed monitoring and evaluation frameworks, including supervision and data quality surveys for disease surveillance, and integrated into core indicators for Liberia
- Embedded within the HIS, Monitoring & Evaluation, & Research and Disease Prevention & Control units to provide technical support and ongoing mentorship to staff
- Led the adaptation of the Integrated Disease Surveillance and Response Technical Guidelines including development of databases and EPI and VHF case investigation forms, maternal death audit and verbal autopsy, and epidemiological bulletins
- Developed a framework, reporting forms, sustainability analysis, and guidelines for Community Event-Based Surveillance
- Trained county and national staff in basic data sciences, including Excel, EpiInfo, Stata, and Tableau, resulting in increases in data use and dashboards at the national level
- Developed metadata sources, including the first Health Facility Registry, updated HMIS/DHIS2 data collection tools

Graduate Research Assistant 2013-2016 | Baltimore, MD

UNICEF Support for Ebola in Liberia

- Supervised a team of students in data management support for the EVD outbreak in West Africa.
- Developed context specific deduplication algorithms, missingness, and data cleaning methods
- Analyzed mortality, symptoms, and care continuum analysis of the epidemic, and implemented probabilistic transmission chains and social network maps from incomplete patient data

Aetiology of Neonatal Infection in South Asia (ANISA)

- Provided epidemiology and data support for post-partum sepsis supplement operating in three sites in Bangladesh and Pakistan
- Performed initial data validation and exploratory analysis to determine possible avenues for secondary research

International Center for Maternal and Newborn Health (ICMNH)

- Mixed methods analysis of parity and gravida data from large household survey evaluating the Tanzanian health system using conditional logistic regression and triangulation with coded qualitative interviews

Child Health Targets Impact Study (chTIS)

- Provided emergency support to resolve data challenges in a high profile multi-site nutrition survey, including standardizing baseline datasets, and producing analysis deliverables for donors and mass media.
- Coordinated production of baseline analysis and dissemination plans, country-specific reports. Led a team of three students and four professors in redevelopment of the analysis plan, timeline, and development of project management tools

Graduate Teaching Assistant — 2015-2016 | Baltimore, MD

- Teaching assistant in an introductory course of 200 students, responsible for managing student concerns, grading, and small group discussions on various introductory topics in public health. Supported the redesign of course structure to a flipped classroom with more active participation

International Organization for Migration — 2016-2017

M&E Consultant — Monrovia, Liberia

- Adapted PRISM assessment for routine assessment of community information systems
- Assessed the impact of the community surveillance programs on the detection of cases of immediately reportable diseases.
- Identified best practices and operational risks for integrating community case referral into national programs
- Evaluated the feasibility, sustainability, and cost-effectiveness of long-term community event-based surveillance

DARE Global Innovations — 2013-2015

Health Informatics Analyst — Washington D.C.

- Revised data and business process flows between health databases in the San Francisco Department of Public Health
- Worked with subject matter experts, IT staff, and private sector developers to author epidemiological requirements for new information systems and identify and propose solutions to institutional bottlenecks impacting timeliness and quality of data

DC State Department of Health — 2010-2013

Statistician Specialist II — Washington D.C.

- Monitored HIV/AIDS and STD morbidity in the DC area, including evaluation of high-risk populations and assessing the impact of socioeconomic shifts on epidemiology.
- Managed multiple 'big data' information systems including the federally managed eHARS system for HIV surveillance, STD Management Information System, and ad-hoc databases for TB, and hepatitis. Developed SAS scripts to routinize manual data management work and free up staff time for active surveillance.
- Introduced business intelligence tools including Tableau dashboards aimed at policy and health education. This included the design and integration of scalable health informatics into the routine business processes and data capacity building within the department

2010

Clinical Research Coordinator – Children's National Medical Center — Washington D.C.

- Managed case recruitment for NIH HIV-related clinical trials for HIV adolescents for ATN093, ATN116, and other HIV-related clinical studies. Conferenced with DC area health providers on increasing access to care among HIV infected youth, and creating structural changes to reduce barriers to care, especially during the transfer to adult care. Reduced the information lag in the state department of health HIV surveillance unit to allow for more timely disease intervention in the youth population.

George Washington University — 2010-2013

Graduate Teaching Assistant – Biostatistics — Washington D.C.

- Instructed a lab section of 25 Masters level students each semester in Introduction to Biostatistics. Teaching duties included aiding in lecture content, proctoring exams, grading student work, and providing tutoring sessions to students.

PROFESSIONAL ACTIVITIES

Member in Good Standing — 2010-Present
American Public Health Association

Certified in Public Health — 2014-Present
National Board of Public Health Practitioners

AWARDS AND FELLOWSHIPS

Global mHealth Initiative Fellowship Award 2015
Johns Hopkins University

Public Health Fellow 2013
International Center for Diarrheal Disease Research
Fellow with the child health unit, working with a DHIS2 pilot to introduce ICD9 coding to two Upazila's in Bangladesh, and implement eMONC mapping within Bangladesh

Department of International Health Tuition Scholarship 2013-2016
Johns Hopkins University

Service to LGBT Population Award 2012
District of Columbia Concerned Providers Coalition

Practicum Research Fellowship Award: Biostatistics Consultant 2011
FHI360 / The George Washington University
Supported a national HIV behavioral and biological serosurvey in survey methodology, data collection tools, and programmed the mobile survey platform.

Dean's Scholarship for Public Health Biostatistics 2010
The George Washington University

Biomedical Fellowship Placement Award: Regulations and Testing Engineer 2009
Sonarmed
Planned and administered testing and documented verification and validation for FDA 510(k) testing. Led manufacturing and supply line restructuring projects for 2nd generation product design

Dean's List of Scholastic Excellence 2009
Purdue University

Summer Undergraduate Research Fellowship Award – School of Materials Engineering 2008
Purdue University
Analyzed stress profiles in unleaded solder to identify a mathematical relationship between stress and formation of common defects leading to electrical failure in sensitive circuitry.

Pfizer Undergraduate Research Fellowship 2007

SKILLS

Analytical	Languages	Tools	Other
Statistical Analysis	SAS	Tableau	Project Management
Monitoring and Evaluation	STATA	ArcGIS/QGIS/Mapbox	Policy Development
Data Cleaning	R	MS Visio/Office	Needs Assessment
Data Visualization and Use	MATLAB	MS Access	Quality Improvement
Survey Design	Python	MS Server	Training
Quantitative Methods		DHIS2	Stakeholder engagement
Program Evaluation			Strategic Planning
			Disease Surveillance
			Technical Writing

PUBLICATIONS & REPORTS

In Preparation –**Ahmed T.**, (2018). Performance of Community Health Volunteers in Community Event-Based Surveillance Programs.

In Preparation –**Ahmed T.**, Peters D (2018). Design and Sustainability of Community Event-Based Surveillance Programs.

Swanson KC, Altare C, Wesseh CS, Nyenswah T, **Ahmed T**, Eyal N, et al. (2018) Contact tracing performance during the Ebola epidemic in Liberia, 2015-2016. PLoS Negl Trop Dis 12(9): e0006762. https://doi.org/10.1371/journal.pntd.0006762

Ahmed, T. (2016), Planning for Sustainable Community and Border Surveillance in Liberia. Lessons Learned from IOM support of MOH CEBS Activities: Key Findings and Recommendations. Monrovia, Liberia

Ahmed, T., Rahman, M., Universal Healthcare in Bangladesh: The future of a post-MDG Health System.

Willis, S., & **Ahmed, T.** (2011). Annual Epidemiology and Surveillance Report. Washington, DC.

Ahmed, T. (2013). Outcomes of Medical Care Transition among HIV+ Youth. Washington, DC. Thesis.

Ahmed, T. (2013). Clinical and Care Dynamics among HIV+ Cases in DC. Washington, DC.

Ahmed, T., Willis, S., Smurzynski, M., & Pappas, G. (2013). Annual Epidemiology and Surveillance Report. Washington, DC.

Taylor, M., Furness, B., & **Ahmed, T.** (2013). Gonorrhea infections diagnosed among persons living with HIV/AIDS: Identifying opportunities for integrated prevention services: New York City, Washington, DC, Miami/Dade County, and Arizona. Journal of Acquired Immune Deficiency.

SCIENTIFIC PRESENTATIONS

Rahman, M, **Ahmed, T.**, (2014). The Way Forward in Post-MDG Bangladesh: MCH Challenges and Successes. Conference. India.

Ahmed, T., Griffin, A., West, T., & Pappas, G. (2012). The Effect of Gentrification on the HIV/AIDS Epidemic. International AIDS Conference. Washington, DC.

Ahmed, T., Mudrick, C., Griffin, A., West, T., & Pappas, G. (2012). Access to Care through Structural Change: The Effect of Public Transportation of Clinical Indicators of HIV. American Public Health Association.

Ahmed, T., Saenz, G., Furness, B, & Griffin, A. (2012). Risk Characterization and Testing Rates of Partner Referred HIV Positive Cases. National STD Prevention Conference. Washington, DC.

Ahmed, T., Smith, C., Griffin, A., West, T., Shaikh, I., & Pappas, G. (2013). Filling the Gaps: Novel use of data dashboards in HIV Surveillance and Analysis. HIV Surveillance Grantees Meeting. Atlanta, Georgia.

Garret, T., **Ahmed, T.**, Saenz, G., Davies-Cole, J., & Furness, B. (2013). Are STD Prevalence Projects Important? Active Case Finding Through a School-based STD Screening Program versus Passive Surveillance. Washington, DC.

Jia, Y., Opoku, J., Burke, L., **Ahmed, T.**, Willis, S., Castel, A., & Pappas, G. (2012). Dynamic trends in HIV/AIDS diagnoses and its biological, sexual and drug use risk factors among adolescents in Washington, DC. Conference on Retroviruses and Opportunistic Infections.

VOLUNTEERING AND ORGANIZATIONS

DC Department of Health Informatics Collaboration – Chair (2011-2013)
Youth HIV Care Committee – Chair (2011-2012)
Biomedical Engineering Society – President (2008-2010)
University Residences - President (2006-2009)
Global mHealth Institute – Advisor/Member (2013-2016)

LANGUAGES

English – Native *Bengali – Native* *Spanish – Intermediate*